April 1999 Vol. 23 No. 4

# TECH BRIEFS

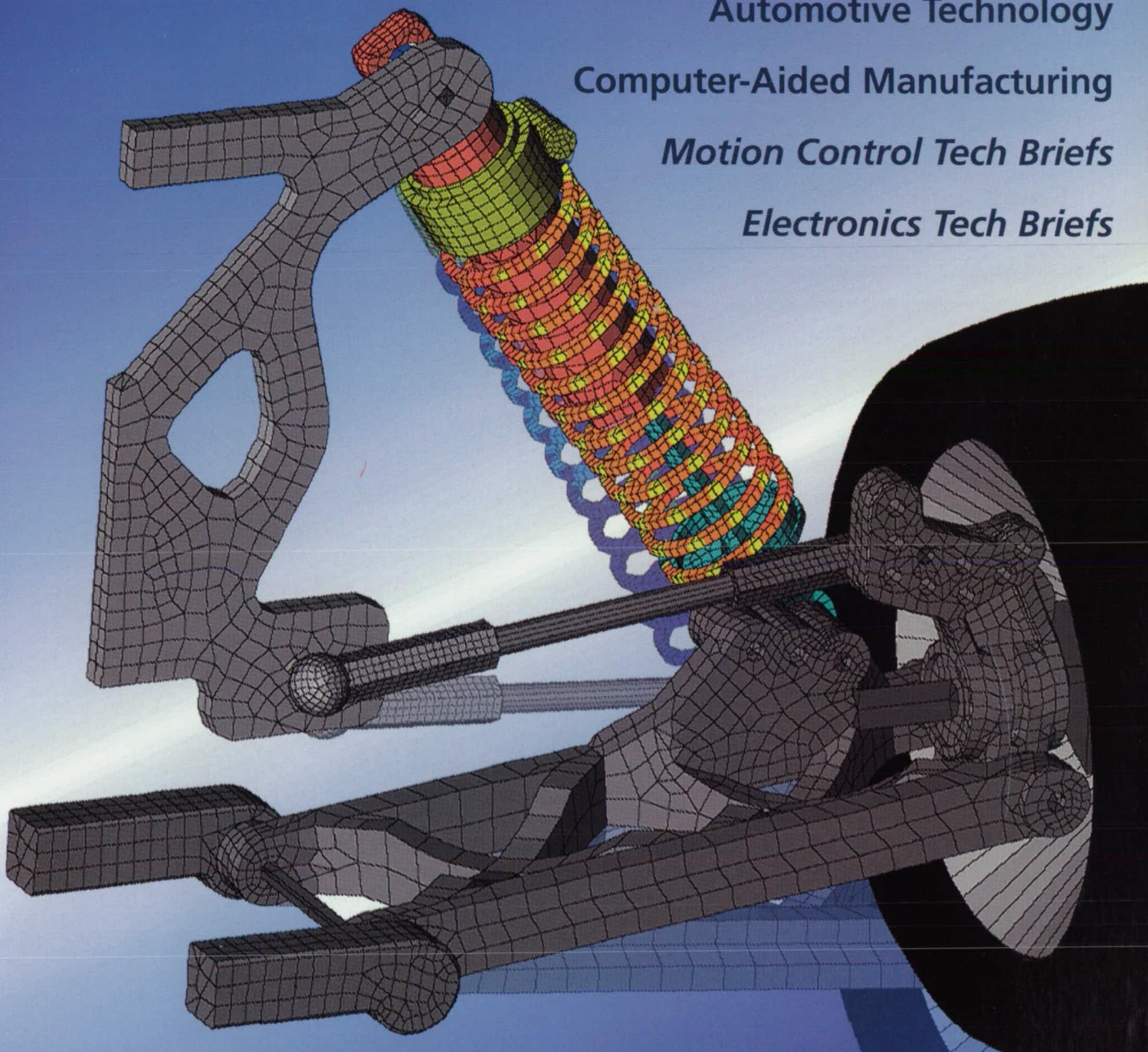
ENGINEERING SOLUTIONS FOR DESIGN & MANUFACTURING

Automotive Technology

Computer-Aided Manufacturing

*Motion Control Tech Briefs*

*Electronics Tech Briefs*



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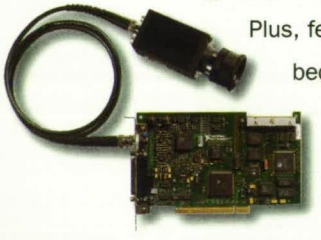

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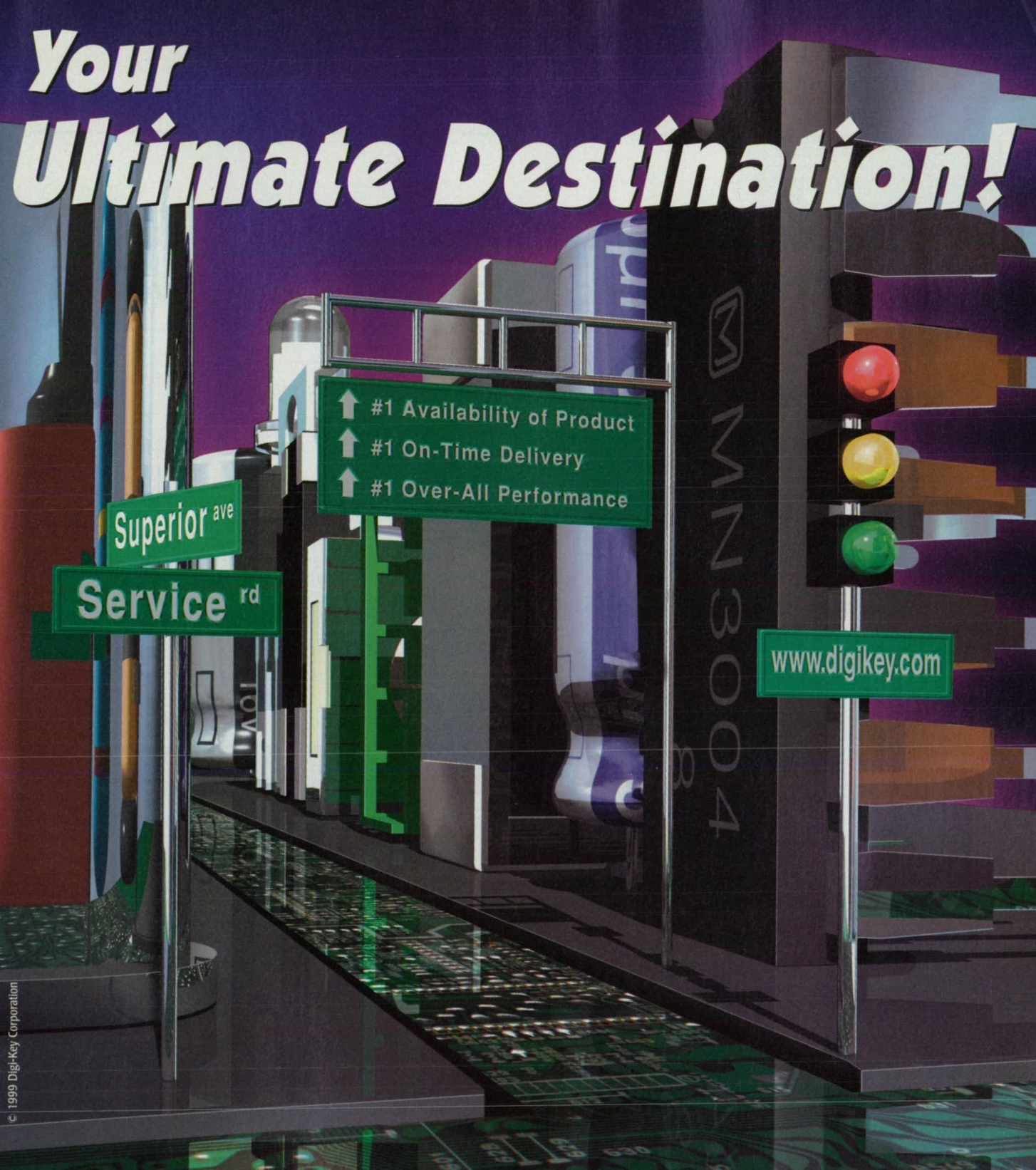


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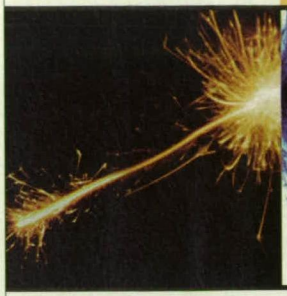

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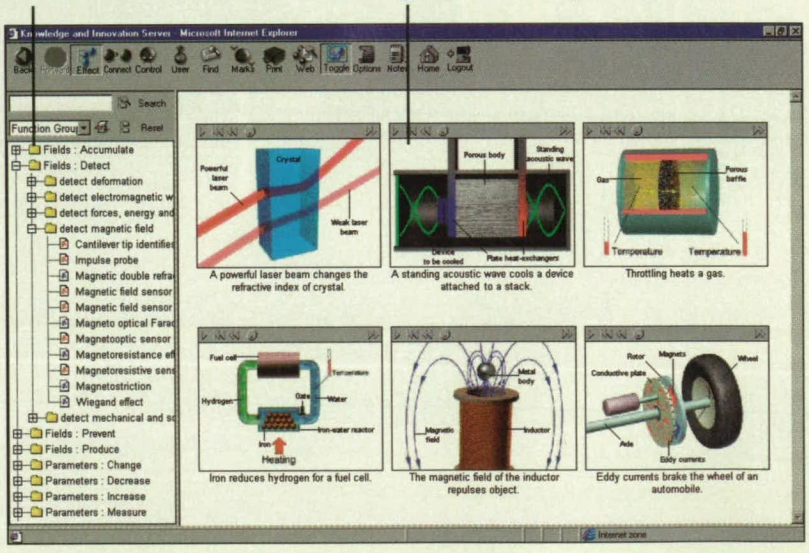


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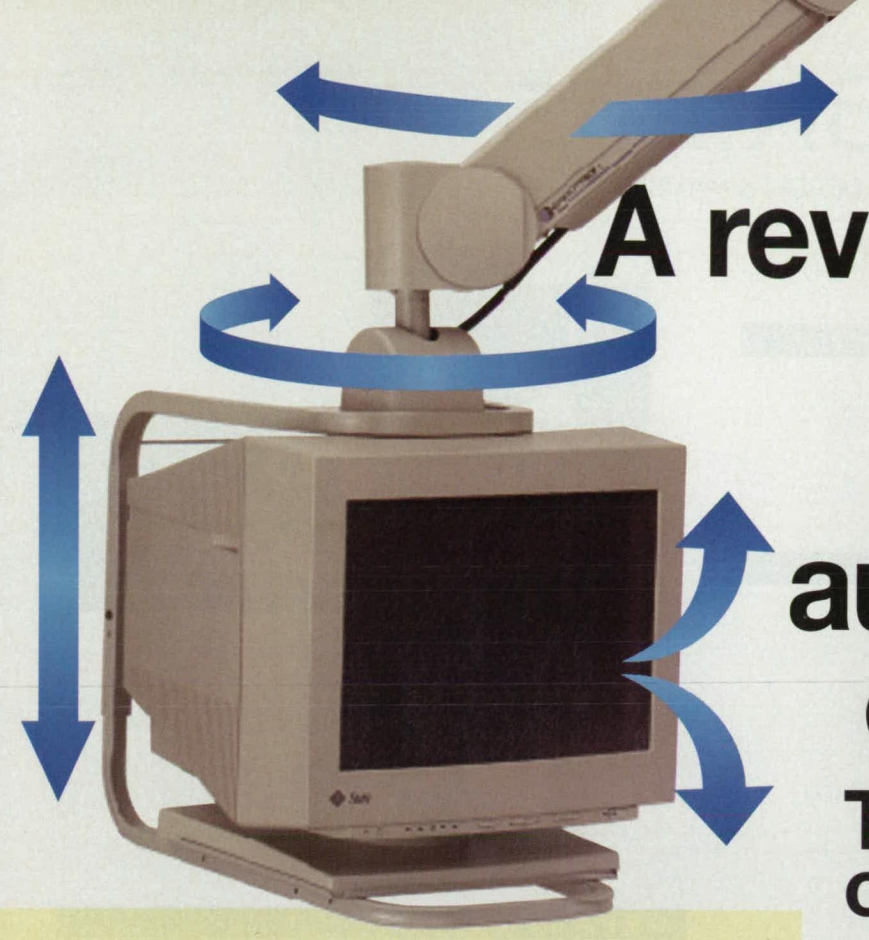

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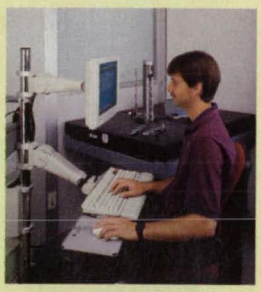

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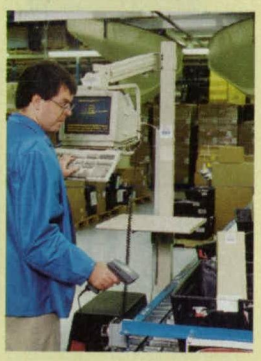

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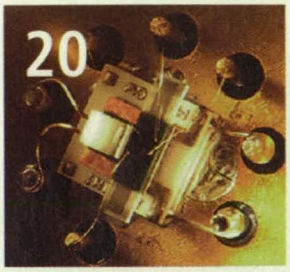




## FEATURES



## BRIEFS



## DEPARTMENTS



## SPECIAL SUPPLEMENTS


**1a – 18a Electronics Tech Briefs**

*Follows page 40 in selected editions only.*


**1b – 14b Motion Control Tech Briefs**

*Follows page 48 in selected editions only.*

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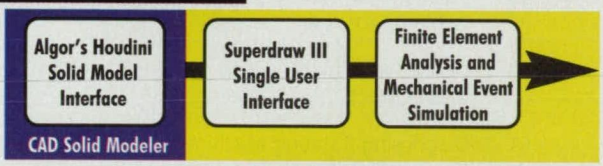
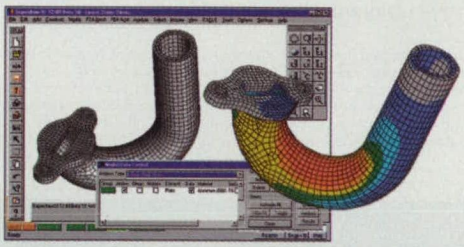
The download also comes with tutorials that give you a guided tour of this new software. These tutorials are available for a variety of analysis types and take you through an analysis from beginning to end, demonstrating the features and capabilities of Release 12 as you go.

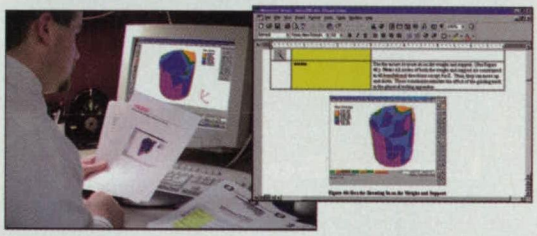
See for yourself how easy and accurate our Release 12 software is by downloading it from **www.algor.com** and trying it for a limited time for free. Or call us at +1 (412) 967-2700 or complete the form below to request a demo CD-ROM.



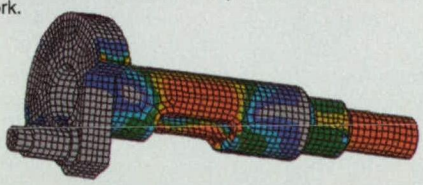

Seamless CAD-interfacing makes using your CAD solid models for FEA, Multiphysics and Mechanical Event Simulation easy by running Algor from within the CAD solid modeler.



Superdraw III, Algor's single user interface for FEA, controls all functions for modeling and Finite Element Analysis or Mechanical Event Simulation.



Algor's downloadable keystroke-specific tutorials give you a walk-through demo of Release 12. Tutorials can be printed out or viewed on the screen as you work.



Unlike other engineering software trial versions that are limited, the trial version of Algor's Release 12 software contains complete Linear and Nonlinear FEA Stress Analysis and multiple Physics-based Mechanical Event Simulation software packages including stress and motion, heat transfer, fluid flow and electrostatic capabilities.

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# Contents *continued*



## PRODUCT OF THE MONTH

**StereoGraphics launches CrystalEyes® Wired for Stereo3D™ visualization on Windows NT workstations.**

**14**

## ON THE COVER

**Dynamic stresses were analyzed on the spring in this car suspension assembly. The analysis was performed using Release 12 of Accupak/VE software from ALGOR, Inc., Pittsburgh, PA. Regular (flexible) elements were used for the spring, while the rest of the suspension was modeled with kinematic elements and a damper element that resulted in processing speed gains in running the Mechanical Event Simulation. See the Special Coverage on Automotive Technology, beginning on page 24, for more information on new innovations for automotive applications.**

(Image courtesy of ALGOR, Inc.)



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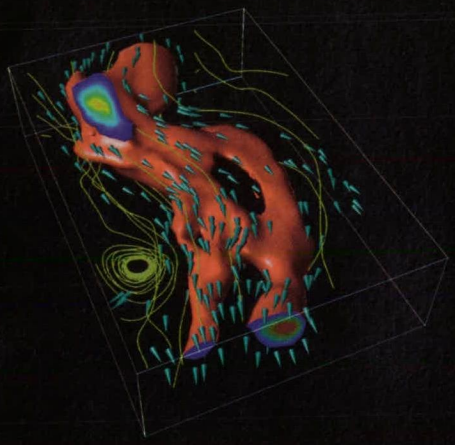
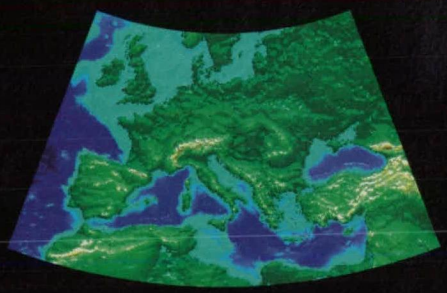


**Volume Visualization**

**MATLAB allows you to visualize volumetric data like this isosurface of wind speed with a cone plot of wind direction.**



**Mapping**

**The new MATLAB Mapping Toolbox can be applied to environmental, oceanographic, and defense applications.**

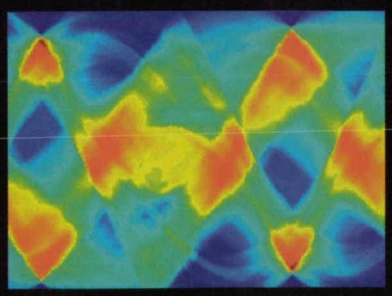


**Image Processing**

**This Radon transform of a spine x-ray illustrates one of the many uses of the Image Processing Toolbox.**

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- UPDATE Image Processing Toolbox
- UPDATE Signal Processing Toolbox
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# NASA Patents

*Over the past three decades, NASA has granted more than 1000 patent licenses in virtually every area of technology. The agency has a portfolio of 3000 patents and pending applications available now for license by businesses and individuals, including these recently patented inventions:*

## Directional Electrostatic Accretion Process Employing Acoustic Droplet Formation

*(U.S. Patent No. 5,722,479)*

Inventor: Richard Oeftering, Lewis Research Center

Traditional methods of manufacturing free-standing metal parts have a number of disadvantages. The present invention is called the directional electrostatic accretion process (DEAP), a method for accreting metal products from minute droplets of molten metal using a nozzleless acoustic device. It is a single-step manufacturing process that converts raw material and design information directly into an end product. An evacuated process chamber houses an accretion product which is bombarded by liquid metal droplets released from a generator that is constantly supplied with molten metal from an external material source. The droplets form a free-surface pool, to which is applied focused acoustic radiation pressure from a source positioned at the bottom of the pool. The DEAP controller controls the release of the droplets from the generator on demand. It is also fed with parameters from the DEAP design workstation, including droplet sizes, impact locations, and velocity derived from the product's dimensional description and pertinent physical and material properties. The droplets are electrostatically charged so that their trajectory can be controlled by electrical fields that guide them to predetermined points on a target, where they solidify, and form the part.

## Gas-Liquid Supersonic Cleaning and Cleaning Verification Spray System

*(U.S. Patent No. 5,730,806)*

Inventors: Raoul E.B. Calmi, Feng-Nan Lin, and Eric A. Thaxton, Kennedy Space Center

High-pressure spray cleaning systems are often employed for cleaning mechanical, electrical, and fluid components and other articles. But traditional systems use very large quantities of solvents, the disposal of which creates an environmental problem. The present invention overcomes this problem by providing a system with a low solvent flow rate in which droplets of cleaning liquid are accelerated to supersonic velocities. One or more converging-diverging spray nozzles are employed to accelerate the gas-liquid mixture to such velocities. High-pressure gas flows to the nozzles, and the cleaning liquid is injected into and mixed with the gas flow stream through an orifice upstream of the converging-diverging sections. The mixed liquid-gas flow subsequently enters the nozzles, where it is accelerated to supersonic speeds as a result of the gas's high pressure and the nozzle profile. This mixture is then impinged upon components or articles that require cleaning or cleanliness verification; its supersonic velocity gives it sufficient momentum at impact to remove contaminants on the component surface, while simultaneously dissolving the contaminant into the liquid, which can then be recaptured for cleanliness verification.

## High-Displacement Solid-State Ferroelectric Loudspeaker

*(U.S. Patent No. 5,802,195)*

Inventors: Curtis R. Regan, Antony Jalink Jr., Richard Hellbaum, and Wayne R. Rohrbach, Langley Research Center

The invention provides a direct-coupled midrange driver of simple and rugged design and low distortion by using a dome-shaped actuator of piezoelectric material to drive the speaker membrane. The actuator is made from a reduced and internally biased oxygen wafer, and generates excursion of the apex of the dome on the order of 0.02-0.05 inch when a rated drive voltage of 350 V rms is applied between the convex and concave surfaces of the actuator. The exceptionally simple design uses a planar speaker membrane with the center part of one side pressed against the actuator rim by prestress from a stretched latex surround member.

*For more information on the inventions described here, contact the appropriate NASA Field Center's Commercial Technology Office. See page 12 for a list of office contacts.*

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Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
*Kirk Sharp*
*(228) 688-1929*
*ksharp@ssc.nasa.gov*

## NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium. To reach the Regional Technology Transfer Center nearest you, call (800) 472-6785.

Joseph Allen
**National Technology Transfer Center**
(800) 678-6882

Ken Dozier
**Far-West Technology Transfer Center**
University of Southern California
(213) 743-2353

Dr. William Gasko
**Center for Technology Commercialization**
Massachusetts Technology Park
(508) 870-0042

J. Ronald Thornton
**Southern Technology Applications Center**
University of Florida
(904) 462-3913

Gary Sera
**Mid-Continent Technology Transfer Center**
Texas A&M University
(409) 845-8762

Lani S. Hummel
**Mid-Atlantic Technology Applications Center**
University of Pittsburgh
(412) 383-2500

Chris Coburn
**Great Lakes Industrial Technology Transfer Center**
Battelle Memorial Institute
(216) 734-0094

**NASA ON-LINE:** Go to NASA's Commercial Technology Network (CTN) on the World Wide Web at **http://nctn.hq.nasa.gov** to search NASA technology resources, find commercialization opportunities, and learn about NASA's national network of programs, organizations, and services dedicated to technology transfer and commercialization.

## NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Carl Ray
**Small Business Innovation Research Program (SBIR) & Small Business Technology Transfer Program (STTR)**
*(202) 358-4652*
*cray@mail.hq.nasa.gov*

Dr. Robert Norwood
**Office of Aeronautics and Space Transportation Technology (Code R)**
*(202) 358-2320*
*rnorwood@mail.hq.nasa.gov*

John Mulcahy
**Office of Space Flight (Code MP)**
*(202) 358-1401*
*jmulcahy@mail.hq.nasa.gov*

Gerald Johnson
**Office of Aeronautics (Code R)**
*(202) 358-4711*
*g_johnson@aeromail.hq.nasa.gov*

Bill Smith
**Office of Space Sciences (Code S)**
*(202) 358-2473*
*wsmith@sm.ms.ossa.hq.nasa.gov*

Roger Crouch
**Office of Microgravity Science Applications (Code U)**
*(202) 358-0689*
*rcrouch@hq.nasa.gov*

Granville Paules
**Office of Mission to Planet Earth (Code Y)**
*(202) 358-0706*
*gpaules@mtpe.hq.nasa.gov*

## NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Wayne P. Zeman
**Lewis Incubator for Technology**
*Cleveland, OH*
*(216) 586-3888*

Dan Morrison
**Mississippi Enterprise for Technology**
*Stennis Space Center, MS*
*(800) 746-4699*

Joe Boeddeker
**Ames Technology Commercialization Center**
*San Jose, CA*
*(408) 557-6700*

Marty Kaszubowski
**Hampton Roads Technology Incubator (Langley Research Center)**
*Hampton, VA*
*(757) 865-2140*

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.

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In Canada Telephone: 1-800-565-2216
**E-mail:** astro-med@astro-med.com • **Web Site:** www.astro-med.com

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30-Channel Data Acquisition System


**AstroDAQ 2**
Portable Data Acquisition System

**For More Information Circle No. 563**

## PRODUCT OF THE MONTH

StereoGraphics Corp., San Rafael, CA, has introduced CrystalEyes Wired, an entry-level stereoscopic eyewear system for mechanical design, CAD, and scientific professionals who work with complex 3D images. The system is designed for Windows NT-based graphics software users and developers for virtual prototyping, design, and simulation. CrystalEyes Wired utilizes OpenGL graphics cards using the Video Electronics Standards Association (VESA) standard 3-pin connector. The user plugs the eyewear's 3-pin connector into a compatible graphics card, and the eyewear is automatically activated when a Stereo3D-capable application is running. Stereo3D is the use of computer technology to recreate the way humans see depth — using both eyes, each with a different perspective. The eyewear is available for $299.

**For More Information Circle No. 738**

## A "Super" Design Tool

NASA's Ames Research Center, Moffett Field, CA, has begun testing the world's first working 256-processor supercomputer, built and programmed by a NASA-Silicon Graphics team. The 256-node single-image Origins 2000 supercomputer is the largest shared-memory machine of its type. The machine is called "Steger" in memory of former NASA Ames computer scientist Joseph Steger, and can execute "Overflow" fluid dynamics code at 20.1 gigaflops, compared with 4.6 gigaflops on a 16-CPU Cray C90. The slower C90 cost $40 million; the Steger cost $10 million.

The supercomputer will help NASA solve the largest aeronautical problems ever attempted. Steger is expected to cut airplane design time and make production of high-fidelity computer simulations more cost-effective. Ames computer scientist Tom Lasinski said that NASA has been trying to do parallel computing since 1986 in a commercial way, "and we've finally done it. Steger not only performs four times faster than our best conventional supercomputer at Ames, but it does it at one-fourth the cost."

*For more information, visit the NASA Ames web site at: http://www.arc.nasa.gov.*

NASA TECH BRIEFS

*1998 Product of the Year*

## Your Winners Are ...

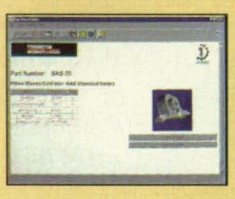
Your votes for the *NASA Tech Briefs* 1998 Readers' Choice Product of the Year Awards have been tabulated, and the winners are:

### Gold Winner

*and Product of the Year*

- LabVIEW Version 5.0 graphical instrumentation software from **National Instruments** (Austin, TX)

### Silver Winner



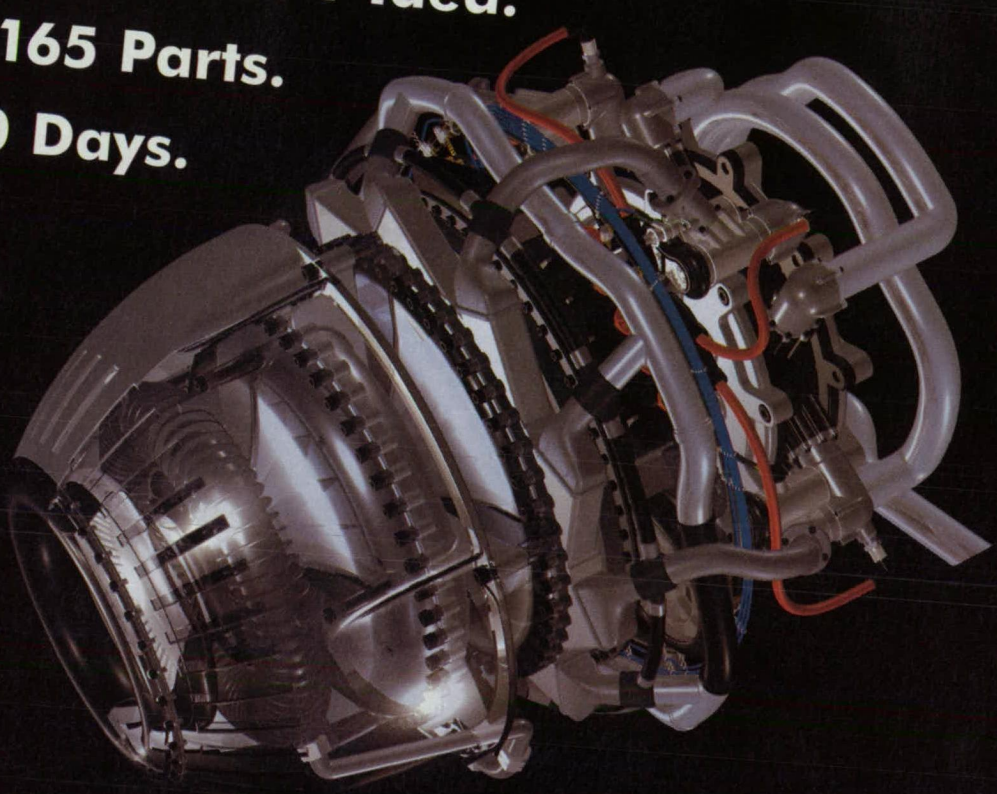
- DesignSuite™ Internet-based 3D CAD model library from **InPart** (Saratoga, CA)

### Bronze Winner

- F30 miniature machine vision system from **Omron Electronics** (Schaumburg, IL)

The awards were presented at a gala reception held during the National Design Engineering Show in Chicago. In next month's issue, we'll feature highlights of the Awards Reception. We'll also announce which readers are the winners of the random drawing for valuable software packages. If you voted in the Product of the Year contest, you're eligible to win!

# 1 Engineer. 1 Idea.
# 1,165 Parts.
# 20 Days.



## Revolutionary

For a long time industrial designer Simon Floyd had an idea for a new type of engine
He also had at his fingertips one of the leading "high end" CAD systems, but the one thing
he didn't have was spare time. "This is a complex assembly and the task of designing it in
any conventional CAD system was just too daunting. However, once I got my hands on
IronCAD, I finally had the power to realize my vision," says Mr. Floyd. IronCAD's unique
Drag & Drop Solid Modeling and Design Flow™ Architecture gave him the power to not only
work fast, but to innovate while he designed. He's become so enthusiastic about IronCAD,
e now offers it to his clients. To see a case study of Simon Floyd's awesome engine design
nd to learn more about how IronCAD is powering the next industrial revolution, log on.

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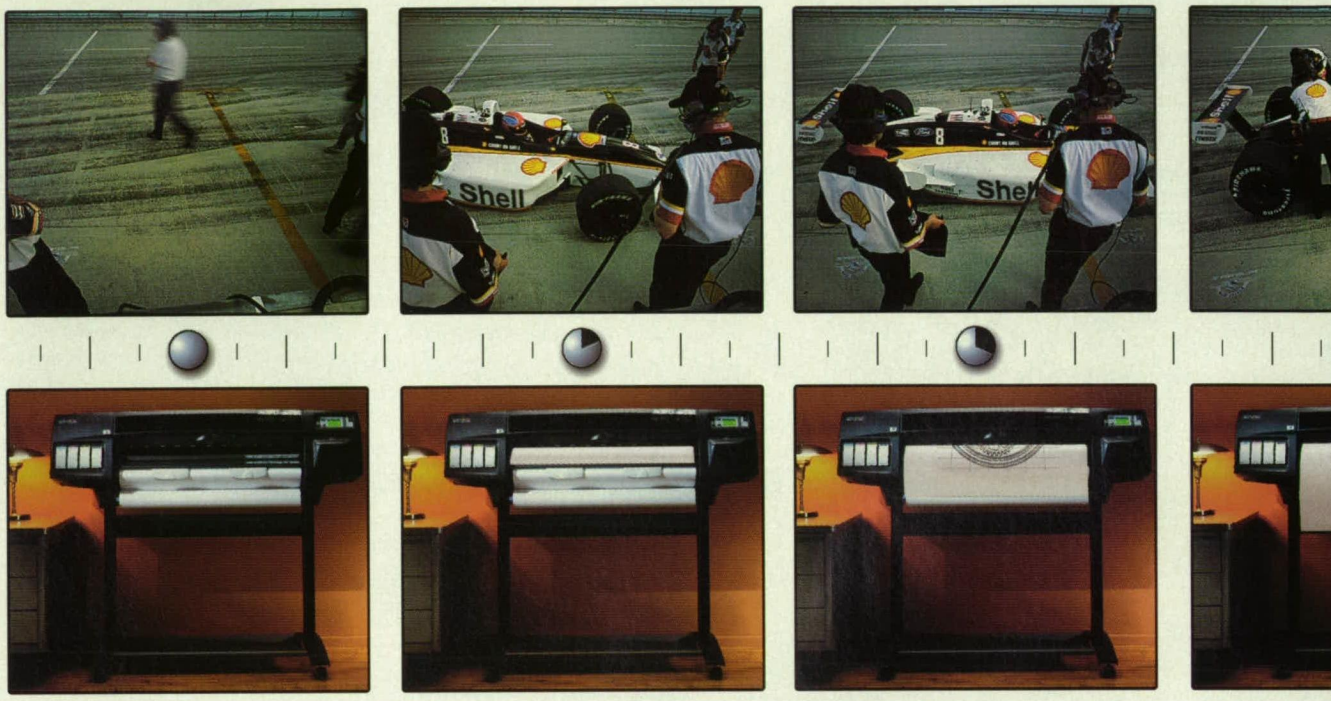


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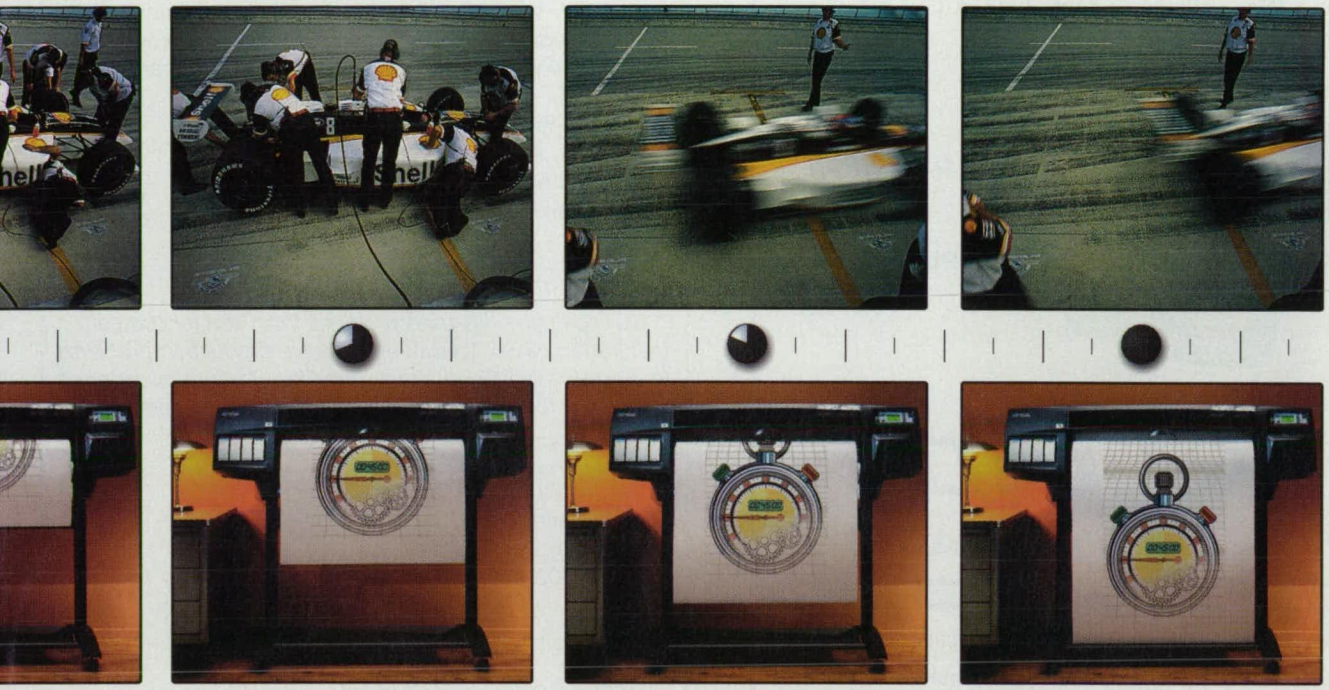
**To find out how to trade in your old large-format printers, call 800-851-1170.**



*(As in six times faster.)*

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Expanding Possibilities

For More Information Circle No. 531

# Reader Forum

*Reader Forum is devoted to the thoughts, concerns, questions, and comments of our readers. If you have a comment, a question regarding a specific technical problem, or an answer to a question that appeared in a recent issue, send your letter to the address below.*

*I design automated conveyors to visually inspect glass. The tech brief entitled "Illumination Device for Inspecting Window Surfaces" (November 1998, p. 68) may prove useful in further work on automated glass inspection. Thank you.*

Robert E. Konkle
Tri Angle Products
Longmont, CO
lakecreek@compuserve.com

*Our company has used products from several companies featured in* NASA Tech Briefs *to solve production problems in our abrasives/linen processing line. Your publication is invaluable for our research and development department. Thanks.*

Ed Lalli
Audio File Co.
Phoenix, AZ
602-242-0718

*From our online Reader Forum:*

*I need to profile temperatures in a commercial oven. Does anyone have a source for pill-sized radio transmitting thermometers that can handle temperatures in the 400 to 600°F range? Thank you.*

John Istre
jistre@msn.com

*I am looking for information on packaging that can be hermetically sealed, and contains a nitrogen environment and optical components for a shelf-life of at least three months. If such a product does not exist, is there a package with a gas filler nipple that could be hooked up to a nitrogen manifold to maintain a nitrogen environment in the package for extended shelf life?*

Joel Solomon
jsolomon@nikon.com

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Post your letters to **Reader Forum** on-line at: **www.nasatech.com** or send to: Editor, *NASA Tech Briefs*, 317 Madison Ave., New York, NY 10017; Fax: 212-986-7864. Please include your name, company (if applicable), address, and phone number or e-mail address.

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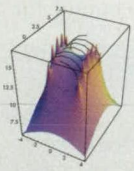

## PRECISE

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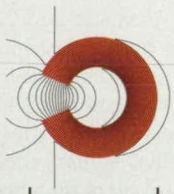

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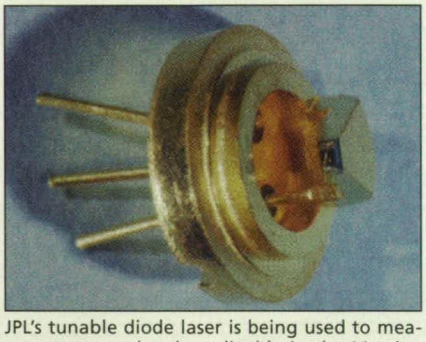
**For More Information Circle No. 546**

# Mission Accomplished

Space technologies that enable microlanders to explore the surface of Mars, spacecraft to find their own way through the solar system, and sensors to capture the faintest of signals, are being developed for a wide range of commercial uses by a new company created solely to bring space benefits down to Earth.

ViaSpace Technologies LLC of Altadena, CA, was founded by Dr. Carl Kukkonen, formerly of NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA. "These technologies are coming to the marketplace via the American space program," said Kukkonen, who is the company's president, CEO, and chief technology officer. "Hence, the company's name."

Kukkonen left his senior management position as Director of JPL's Center for Space Microelectronics Technology to set up ViaSpace. He has obtained options for exclusive licenses from the California Institute of Technology (Caltech) for five technologies that JPL, a division of Caltech, has developed for NASA space exploration missions. Kukkonen, a physicist who has spent 25 years in advanced research and development, believes these technologies will find profitable and commercial applications in such diverse fields as communications, agriculture, medicine, industrial controls, and environmental monitoring.



JPL's tunable diode laser is being used to measure water and carbon dioxide in the Martian atmosphere.

The specific technologies licensed by ViaSpace are:

- An infrared sensor that can create clear black and white images of objects or scenes in total darkness from the heat that every substance — whether hot, room temperature, or sub-zero cold — gives off.
- A laser diode that can be "tuned" like a radio to the specific telltale frequencies that molecules and compounds absorb.
- Digital cameras and systems based on the active-pixel-sensor, an ultra-low-power microelectronic chip that requires only 1/100th the power of the charge-coupled devices used in many consumer video products.
- A compact but extremely sensitive humidity sensor called a microhygrometer, capable of detecting as little as a spoonful of water sprayed inside a volume as large as the White House.
- A research effort still being negotiated by ViaSpace and Caltech.

In some cases, according to Kukkonen, the technologies will significantly improve existing products or processes based on older technologies, by making them smaller, lighter, cheaper, better-performing, or all of the above. In other cases, he expects the technologies will lead to new products or processes beyond our imagination today. "NASA and the Department of Defense have invested millions of dollars in developing these technologies for the needs of specific missions," said Kukkonen. "With a modest additional investment, ViaSpace can transform this government technology for the commercial marketplace."

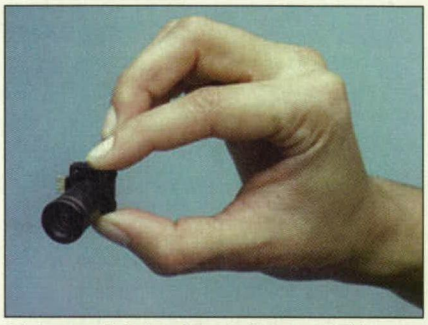
## Taking Technology Further

Dr. Dwight Duston, assistant deputy for technology at the Ballistic Missile Defense Organization, said the Defense Department is happy to have ViaSpace as a commercial source of Quantum Well Infrared Photodetectors (QWIPs). "We need quantum well infrared detectors for missile detection and tracking, and we intend to demonstrate them on one of our space missions this year."

The QWIP is based on gallium arsenide, a semiconductor that is used extensively in cell phones and fiber-optic communications. Minute structures only a few atoms wide called quantum wells are introduced into the gallium arsenide to trap electrons that are then released when infrared light is incident on them. The unique advantages of QWIPs are long wavelength operation and large-size focal plane arrays with high uniformity. QWIPs can be made to be sensitive to infrared radiation from 6 to 25 micrometers.

The tunable diode laser can determine the presence and concentrations of different gases, both naturally occurring and manmade, in atmospheres as well as industrial and medical settings. The laser is a strained layer quantum well semiconductor laser in indium gallium arsenide on an indium phosphide substrate. Using an internal grating constructed by electron beam lithography, the laser delivers high spectral purity, stability, and wavelength control.

NASA is using a tunable laser diode to measure the distribution of water vapor in Atlantic Ocean hurricanes, and is planning to fly several lasers aboard a spacecraft bound for Mars this year to see how much water vapor and carbon dioxide are present in the Martian atmosphere. The laser also has great potential for industrial process controls and fiber-optic communications.



Miniature digital active-pixel-sensor visible camera with the imager, control electronics, and analog-to-10-bit digital converter, integrated on a single chip using only 20 mw of power.

The JPL active-pixel-sensor is made with the standard CMOS process so that the imager and all its drive circuitry, together with an analog-to-digital converter, can be made on the same silicon chip. The technology is aboard NASA's New Millennium Deep Space One mission that was launched last October to image asteroids and comets. These tiny units will provide detailed images of their surfaces. Here on Earth, Kukkonen expects the digital camera-on-a-chip to lead to a new generation of video cameras, video conferencing systems, machine vision "eyes," security systems, and toys. When combined with JPL's advanced communications technologies, the low-power camera has been demonstrated as a battery-operated, wireless system capable of transmitting images from remote sites to a base station up to a kilometer away.

Weather monitoring is an obvious use for the microhygrometer. JPL already has made a prototype microweather station the size of a soda can with one of these humidity sensors, and has tested it on balloon and aircraft flights. The microweather station

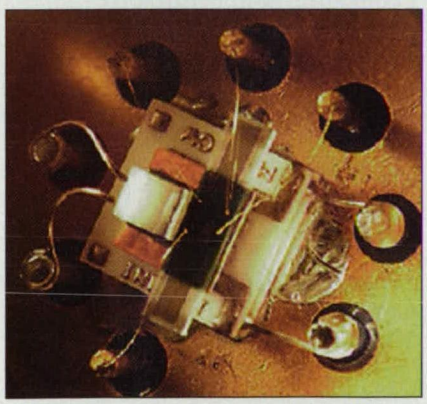
measures temperature, pressure, humidity, and location, and transmits this data to the base station. The surface acoustic wave microhygrometer represents a breakthrough in sensitivity, speed, size, and power consumption.

Applications include environmental and weather monitoring, process control in the paper industry, and in medicine. An even greater market might be in high-technology factories. Said Kukkonen, "There are some fabrication processes, like those of semiconductors, where water vapor and other gases must be measured with extreme accuracy."

## On Their Way to a Shelf Near You

ViaSpace is quickly commercializing these technologies. The company has formed a joint venture with the Rainbow Group of Edmonton, Alberta, Canada, to develop the infrared photodetectors for certain military and civilian uses. Cam Chehayeb, President and CEO of the Rainbow Group, explained that they see "a large commercial and military market for the Quantum Well Infrared Photodetector. Our joint venture with ViaSpace will have its first products in less than a year."

ViaSpace also has an agreement with Omicron Technologies of Miami, FL, to develop new imaging systems based on



JPL's dewpoint microhygrometer is used for environmental and weather monitoring, and process control in a variety of industries.

the active-pixel-sensor digital camera-on-a-chip. "Together with ViaSpace, we will develop still and wireless cameras based on the active pixel sensor technology. We expect to reach the marketplace this year," according to Barrett Sleeman, President and CEO of Omicron.

To augment its cutting-edge expertise, ViaSpace has joined JPL's Technology Affiliates Program, which will allow the firm to have access to the JPL scientists and engineers who developed these technologies, and to the Laboratory's microelectronics fabrication facilities. "Caltech is pleased to encourage an entrepreneurial company like ViaSpace, which seeks to commercialize Caltech and JPL technologies as a means of creating new industries and jobs," said Dr. David Baltimore, president of Caltech.

*For more information, contact Dr. Carl Kukkonen at ViaSpace Technologies, LLC, 2400 Lincoln Ave., Altadena, CA 91001; Tel: 626-296-6310; Fax: 626-296-6311; e-mail: kukkonen@viaspace.com; or visit the web site at: www.viaspace.com.*

# Commercialization Opportunities

## Miniature Lambda Sensors for Engine-Control Systems

Proposed sensors would incorporate nanoceramics to measure air/fuel ratios in the exhaust gas flows of advanced aircraft engines. These sensors would feed data to adaptive control systems that, in turn, would adjust engines to maximum efficiency. Applications are also envisioned in automotive and furnace industries.
(See page 24.)

## Circuit for Automatic Tunneling-Controlled Golay Cell

A new module, designed specifically for sensing infrared radiation indicative of the concentration of glucose in blood, features low noise, high gain, and low power consumption, all of which make it attractive for other infrared sensing applications.
(See page 33.)

## Improved Fabrication of Electrodes for Methanol Fuel Cells

The improved method provides for faster production with more efficient utilization of expensive catalytic metals. The new method is better suited for mass production.
(See page 38.)

## Liquid-Circulation System Keeps Aircrew Members Cool

A new cooling garment worn under the flight suit keeps test pilots more comfortable. The system consists of a garment that is connected to a unit mounted inside the cockpit. The unit pumps the coolant and serves as heat exchanger. Hospitals may find this development useful for emergency treatment of high fever and injuries.
(See page 41.)

## Programmable Multizone Directional-Solidification Furnaces

These furnaces feature compact design, increased versatility for programming a variety of stationary and moving temperature profiles, and high thermal efficiencies.
(See page 44.)

## Sensor for Monitoring Concentration of Methanol in Water

This sensor is expected to be particularly useful in continuous monitoring and control of the concentration of an aqueous solution of methanol metered into a liquid-feed, direct-oxidation methanol fuel cell.
(See page 46.)

## Foam Heat Exchangers

Advantages would include smaller, lighter heat exchangers, significantly reduced chances of obstruction, and lower manufacturing costs.
(See page 48.)

# Miniature Lambda Sensors for Engine-Control Systems

**The feasibility of sensors made from a nanoceramic has been demonstrated.**

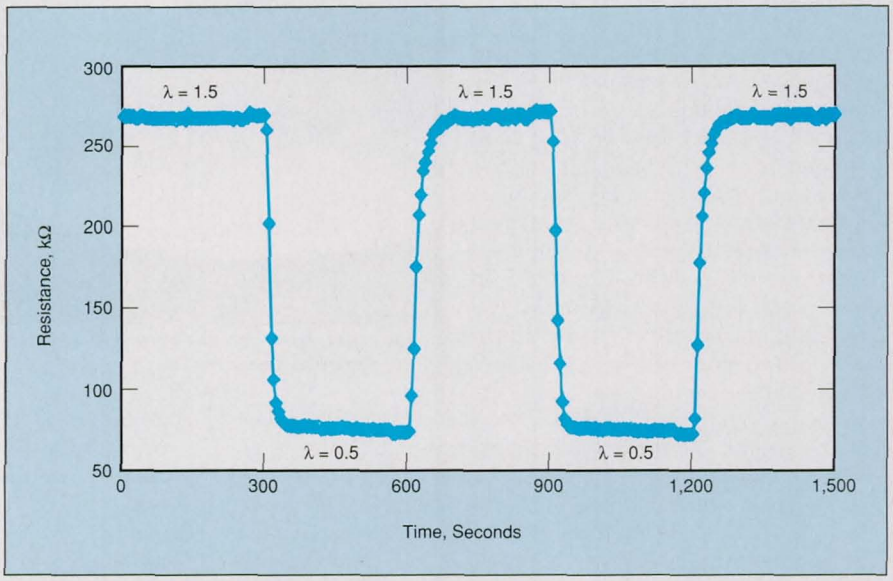
*Lewis Research Center, Cleveland, Ohio*

Small, lightweight sensors that exploit the unique characteristics of nanoceramics are being developed for use in measuring air/fuel ratios in the exhaust gas flows of advanced aircraft engines. Adaptive control systems would process the readings from these sensors, along with other sensory and control inputs, to generate engine commands to maximize fuel efficiency and minimize emissions of undesired exhaust products. Sensors and control systems of this type could also be used to enhance the operation of automotive and other internal-combustion engines that burn a variety of fuels, and of stationary combustors like furnaces and kilns.

The developmental sensors are called "lambda sensors" because the fuel/air ratio of particular relevance in this context is denoted by the symbol λ (lambda). The defining equation is λ ≡ [actual value of (density of oxygen/density of fuel)]÷[stoichiometric value of (density of oxygen/density of fuel)]. Ordinarily, a monitoring and control system would be designed to keep λ as close as possible to 1. Heretofore, commercially available sensors have not offered the rapid response and high sensitivity needed for monitoring and controlling λ when λ varies from substoichiometry (0.5) to superstoichiometry (1.5).

Nanomaterials and, in particular, nanoceramics, are novel high-precision materials that are synthesized with selected crystalline sizes <100 nm. The microstructure of a typical nanomaterial is such that there is a very large concentration of grain boundaries, and between 20 and 60 percent of the atoms are interfacial. The large interfacial area is conducive to rapid equilibration and rapid diffusion, both of which are essential for rapid and reliable sensor operation.

Equally important, the complex of electrical and chemical interactions at the interfaces and within the bulk crystalline material can be exploited for sensing chemical species of interest. The net effect of these interactions is that the electrical resistance of a piece of nanoceramic exposed to pure air or oxygen differs from its electrical resistance during exposure to air or oxygen with a fuel or other analyte gas mixed in, and the ratio between the two resistances can be taken as a measure of the concentration of the analyte in the gas mixture. A major portion of the present effort to develop λ sensors is devoted to optimizing crystalline structures, mostly by tailoring grain sizes, in order to exploit combinations of bulk and surface effects to obtain rapid response and high sensitivity.




The **Electrical Resistance of a Pellet of $Ga_2O_3$ Nanoceramic** was measured in a flowing mixture of CO, $O_2$, and $N_2$ as the composition of the mixture was alternated between λ = 0.5 and λ = 1.5.

Initial experiments have been performed on λ sensors made from nanoscale $Ga_2O_3$ powders that were synthesized by a solvent-precipitation technique and by a thermal-quench technique. Fabrication of each sensor began with squeezing of $Ga_2O_3$ powder at a pressure of 2,000 psi (14 MPa) to form a pellet. The pellets were sintered for one hour in air at a temperature of 1,300 °C. By use of silver paste as a bonding agent, the pellets were bonded to an alumina substrate with platinum electrodes for measuring the electrical resistance of the pellets.

The figure is a plot of data from an experiment in which a sensor was exposed to a synthetic exhaust mixture of CO (regarded as the fuel gas), $O_2$, and $N_2$. In this experiment, λ was made to alternate between 0.5 and 1.5. The plot indicates the feasibility of λ sensors made from $Ga_2O_3$ nanoceramics, though the response time is still longer than the maximum (about 10 ms) allowable in engine-control applications. Refinements in the sensor materials and designs will be necessary to reduce response times. Further research will also be needed to ensure stability and reproducibility of sensor characteristics, to increase durability, to enhance sensitivity, to achieve further miniaturization, and to establish temperatures and develop temperature controls for reliable sensor operation.

*This work was done by Chuanjing Xu and Tapesh Yadav of Nanomaterials Research Corp. for* **Lewis Research Center.** *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16700.*

## Sensor Technology Helps Create "Wind Tunnel in the Sky"

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NASA's Ames Research Center recently launched a new hypersonic flight testing system capable of performing 11 or more independent, high-velocity flight experiments. The 300-pound science payload was designed to eject multiple, inexpensive hypersonic (Mach 7+) flight experiments of different configurations. The experiments were conducted to develop and test technologies for next-generation planetary exploration missions, and to study problems associated with high-speed flight.

**Image taken from orbit as part of the Scramjet flight dynamics investigation.**

Called a "wind tunnel in the sky" by Marcus Murbach, principal investigator with the Space Projects Division at NASA Ames, the test method uses the sounding rocket to achieve a very high altitude, from which the experiments are staged. As the experiments return to Earth, each achieves the desired Mach number. The method provides data and information that cannot be gathered using ground-based wind tunnels. "We wanted to develop a generic facility that would easily accommodate different sorts of experiments," said Murbach. "The key to our performing the multiple experiments inexpensively is developing a different method to obtain the experimental data."

Among the 11 experiments launched were the full-scale Pascal Probe, an element of the Mars Network mission intended to deliver 24 surface pressure stations to the Martian surface; a sample return vehicle concept for returning Mars soil samples to Earth; and a transpiration cooling system, in which fluid is injected into the stagnation region of an entry vehicle, causing the local heating rate to drop dramatically.

Crossbow three-axis accelerometer packages and the DMU-6 six-axis inertial measurement unit were used to determine the aerodynamic coefficients of the initial test of ballistic entry concepts. "What is really exciting about this is the ability to perform inexpensive development of hypersonic flight concepts involving lifting surfaces and shapes," said Murbach. "This may be the beginning of a new flight test methodology that will greatly help to advance the state of the art in this field."

An inexpensive CCD camera was placed on the sounding rocket above the experiment bays, allowing the mission events to be viewed in real time. This also permitted immediate appraisal of critical separation and staging events. The simultaneous broadcast on the Internet allowed experimenters, team members, and other groups to participate during the flight. The launch site can be viewed at http://cmex.arc.nasa.gov/srocket.

**For More Information Circle No. 755**

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## System Captures NASA Satellite Data

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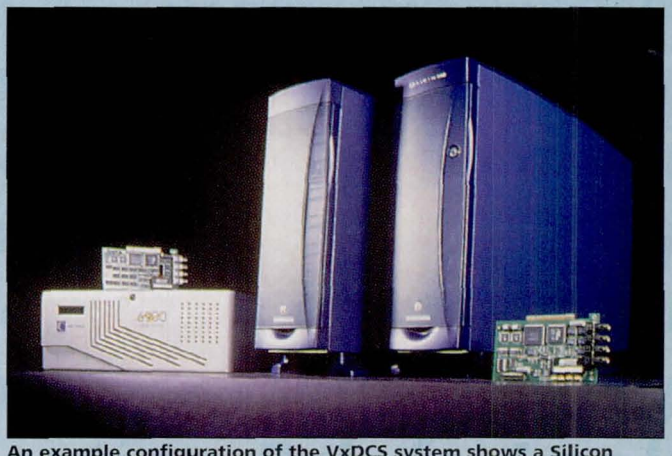
NASA contractor TRW of Fairfax, VA, is using ten VxDCS data capture systems for use in NASA's Earth Observation Satellite (EOS) Data Operation System. The VxDCS allows satellite and other high-rate data streams to be captured directly onto computer disks for processing, storage, retransmission, distribution via networks, or transferring data to archive media.

The technology provides an alternative to high-density tapes and digital recorders (HDDRs). Each system purchased by TRW consists of a UNIX workstation computer with a PCI bus; Vexcel's integrated circuit boards for data capture and export; and a disk array for storage. Historically, data from satellites has been captured on high-density tapes, since the downlinked data rates exceed the capacity for capturing data directly onto computer disks. The Vexcel systems can capture data at speeds in excess of 320 MB/second.

The systems will be used to capture data at three automated, or unmanned, ground stations collecting EOS data north of the Arctic Circle. The data will be collected and retransmitted to a communications satellite to be subsequently downlinked and processed at NASA's Goddard Space Flight Center in Greenbelt, MD. The goal in using the data capture systems is to allow the ground stations to be operated remotely from Goddard.



**An example configuration of the VxDCS system shows a Silicon Graphics Origin computer, Ciprico RAID, and Vexcel's PCI-DIF™ boards.**

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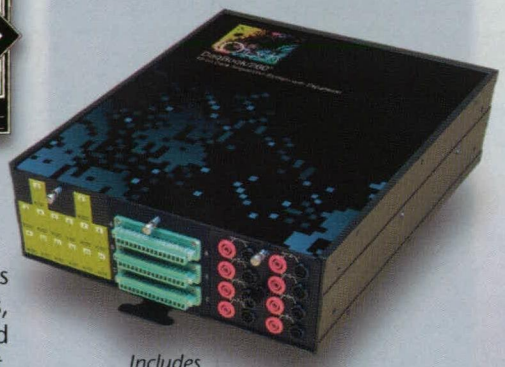

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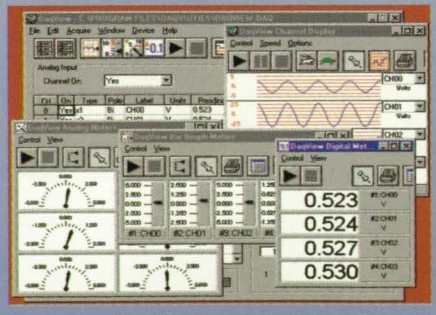

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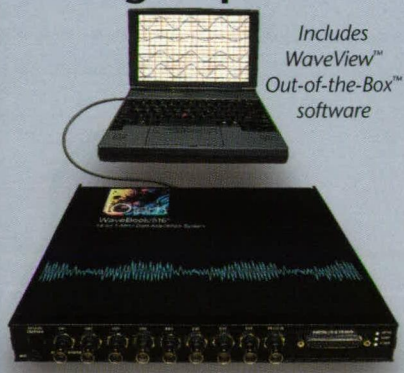

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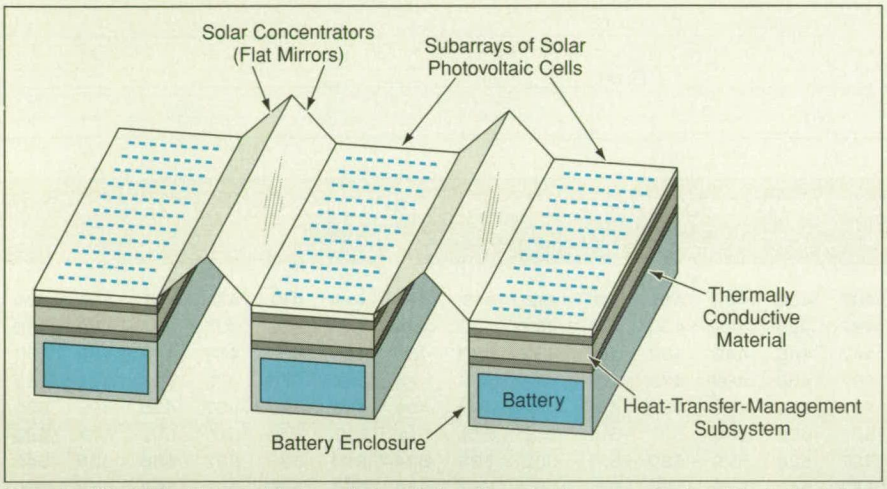
# Solar Heating of Batteries in Cold Environments

## Heat that would otherwise be rejected would keep batteries at operating temperatures.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

According to a proposal for small electric-power systems that must operate in cold environments, heat released in the operation of solar photovoltaic arrays with solar concentrators would be utilized to maintain batteries at operating temperatures. The proposal is straightforward and does not impose a requirement for any fundamental new technological developments. The proposal is applicable to secondary batteries, which are charged by use of the photovoltaic arrays.




**Batteries Would Be Mounted** below photovoltaic cells and solar concentrators. Waste heat from the solar concentrators and photovoltaic cells would be used to maintain the batteries at operating temperatures.

Common batteries that contain aqueous electrolytes perform poorly at temperatures below –10°C, because the electrolytes freeze and/or become viscous, with consequent degradation of ion-transport properties. The low-temperature performances of some lithium primary and lithium-ion secondary batteries have been improved by use of nonaqueous electrolytes, but there remains a problem of what to do in environments colder than their lowest operational temperatures. The proposal offers an alternative solution for batteries of all types.

The typical energy-conversion efficiencies of modern solar photovoltaic cells range from 5 to 25 percent; consequently, most of the solar radiation focused by solar concentrators onto solar photovoltaic cells is converted to heat. It is necessary to remove excess solar heat because the efficiencies of solar photovoltaic cells decrease with increasing temperature. Heretofore, various forms of active and passive cooling have been

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used to remove heat from solar photovoltaic cells. The basic concept of the proposal is to divert some or all of this heat to the batteries instead of rejecting all of it to the environment.

The figure illustrates an example of how the proposal might be implemented in a system in which the solar concentrators are simple flat mirrors located between subarrays of solar photovoltaic cells. The batteries would be placed behind the subarrays. Preferred configuration might consist of thin type batteries coupled with photovoltaic cells which would be considered to be amenable to a wide range of applications. The batteries would be thermally connected to the subarrays via heat-transfer-management subsystems and layers of heat-conductive material. Depending upon the specific application, the heat-transfer-management subsystems in a given system might contain heat pipes, thermostats, and/or heat reservoirs containing phase-change materials. Phase-change materials could be used to reduce temperature fluctuations. Heat pipes could be used during periods of low insolation to transfer, to the batteries, heat stored previously during peak insolation. Thermostats could be used during peak insolation to break the thermal connections when temperatures exceed a specified value.

The innovations discussed here are formulated concepts, and have not been fully reduced to practice.

*This work was done by Julian Blosiu, Marshall Smart, Garry Burdick, and Subbarao Surampudi of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category. NPO-20284*



# Thermal Batteries Made With Nanostructured Material

## Power densities can be increased by use of finer-grained cathode powder.

*Lewis Research Center, Cleveland, Ohio*

Early experiments in a continuing research program have demonstrated that thermal batteries made from powdered solid electrode and electrolyte materials can be improved by use of smaller (nanometer vs. micrometer size) cathode powder grains. The improvements include the possibility of fabricating and using thinner cathodes, plus increases in mechanical robustness, thermal stability, and overall power density.

A thermal battery is a primary battery that is activated by heating to melt the solid electrolyte to supply electrical power for a limited time. Thermal batteries are highly reliable energy

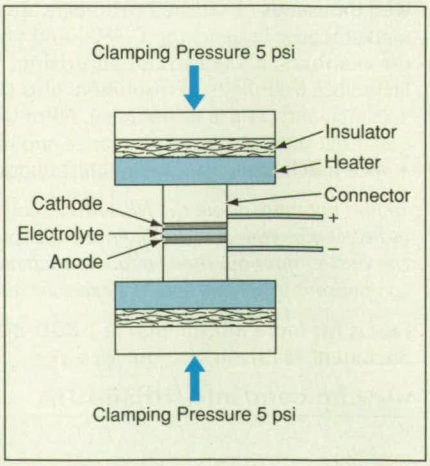


Figure 1. A **Basic Single-Cell Thermal Battery** contains electrode and electrolyte disks. Unlike power cells used in many commercial products, this cell must be activated by heating to melt the electrolyte.

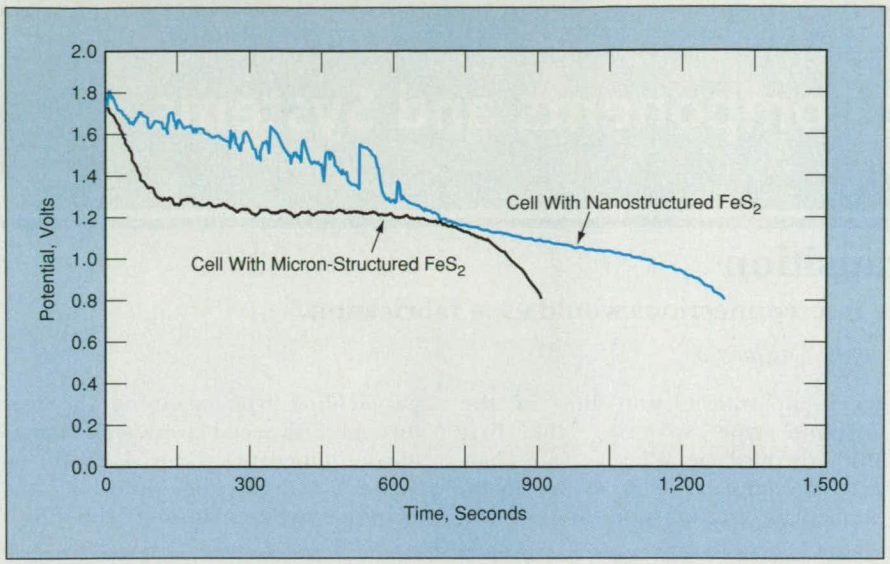


Figure 2. **Voltages Generated by Cells** of the types described in the text were measured during constant-current (0.4 A) discharges at a temperature of 400 °C.

sources with high power densities and long shelf lives. They are particularly useful for supplying short-term power in expendable weapons (e.g., torpedoes and projectiles) and exploratory spacecraft; likely future commercial applications could include generating emergency power in aircraft and providing startup power for automobiles with weak batteries.

A single-cell thermal battery of the type under study in this research program (see Figure 1) contains an electrolyte disk stacked between an anode and a cathode disk. Each disk is made by cold-pressing the appropriate cathode, electrolyte, or anode powder. Heretofore, thermal batteries have been manufactured by techniques that impose lower limits on disk thicknesses needed to ensure adequate mechanical strengths. Accordingly, achievable power densities and other performance characteristics have been limited, and progress toward miniaturization and toward enhancement of activation characteristics and of safety has been impeded.

The anode material used in the experiments was an alloy of 44 percent Li + 56 percent Si, supplied as a powder of micron-size particles. The anode disks were formed by pressing this powder in a 2-cm-diameter round steel die at 6,000 psi (41 MPa). The electrolyte material included a powder of eutectic salt comprising 45 percent LiCl + 55 percent KCl. To strengthen the electrolyte disks, the eutectic salt powder was blended with 35 percent of MgO powder. The blended powder was pressed at 4,000 psi (28 MPa) to form electrolyte disks.

The cathodes were made from a blend of 68 percent $FeS_2$ powder, 30 percent of the eutectic salt powder, and 2 percent of $SiO_2$. The blend was pressed into disks at 4,000 psi (28 MPa). To provide a basis for comparison, the $FeS_2$ powder used to make some cathode disks had particle sizes of the order of 1 μm, while that used to make the other cathode disks had an average particle size ≈25 nm. The nanostructured $FeS_2$ powder was made by ball-milling the micron $FeS_2$ powder.

For equal weights of blended powder and identical pressing conditions, the cathode disks made from nanostructured $FeS_2$ came out 23 percent thinner and thus 30 percent denser than the cathode disks made from micron-scale $FeS_2$. The nanostructured disks were found to be more robust than the others by comparison of degrees of shattering in a simple drop test. Thus, it was demonstrated that thinner, more robust cathode disks can be made by use of nanostructured instead of micron-scale $FeS_2$ powder.

In thermogravimetric tests of the thermal decomposition of $FeS_2$ into FeS + S, the nanostructured-$FeS_2$ cathodes were found to be more stable. Finally, the discharge electrical performances of batteries containing nanostructured-$FeS_2$ cathodes were found to be superior to those containing micron-scale-$FeS_2$ cathodes (see Figure 2): The discharged electrical energy per unit mass averaged over all the cell material (electrodes + electrolyte) was found to be 109 J/g in the nanoscale case and 58 J/g in the micron-scale case.

*This work was done by Ming Au, Yabin Lei, and Tapesh Yadav of Nanomaterials Research Corp. for* **Lewis Research Center.** *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16698.*

# Interlayer Stripline Transition

## Elimination of vertical conductive interconnections would ease fabrication.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed multilayer metal-film/dielectric-plate laminate would serve as a passive radio-frequency (RF) interlayer stripline transition. This device is designed to provide RF coupling from (a) an input transmission line of the stripline type spanning the first through third metal layers, with characteristic impedance $Z_{0s}$ to (b) an intermediate transmission line of the parallel-line type spanning the first through fifth metal layers, with characteristic impedance $Z_{0p} \approx Z_{0s}$ to (c) an output transmission line of the stripline type spanning the third

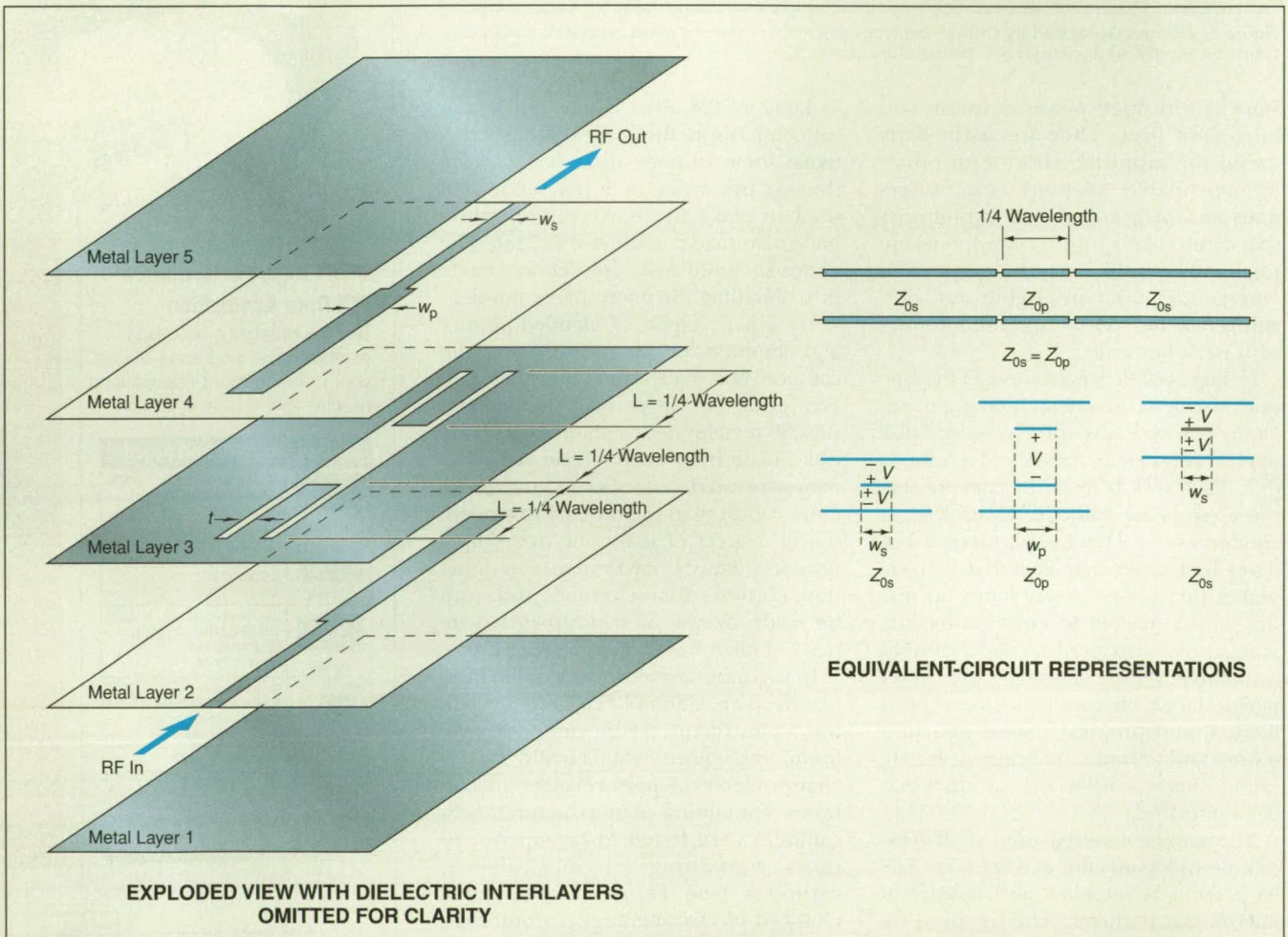


Figure 1. The **Absence of Through-the-Thickness Interconnections** eases fabrication. Interlayer coupling is achieved solely via the interlayer electromagnetic field.


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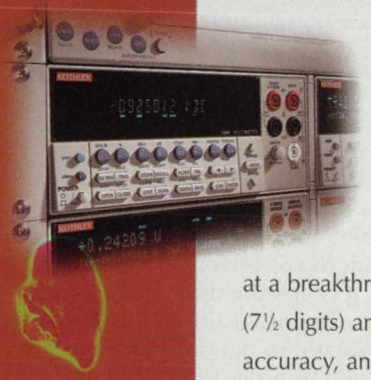

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| • AC amps | 1μA – 3A | 1μA – 3A | 100pA – 2.1A | 100pA – 2.1A |

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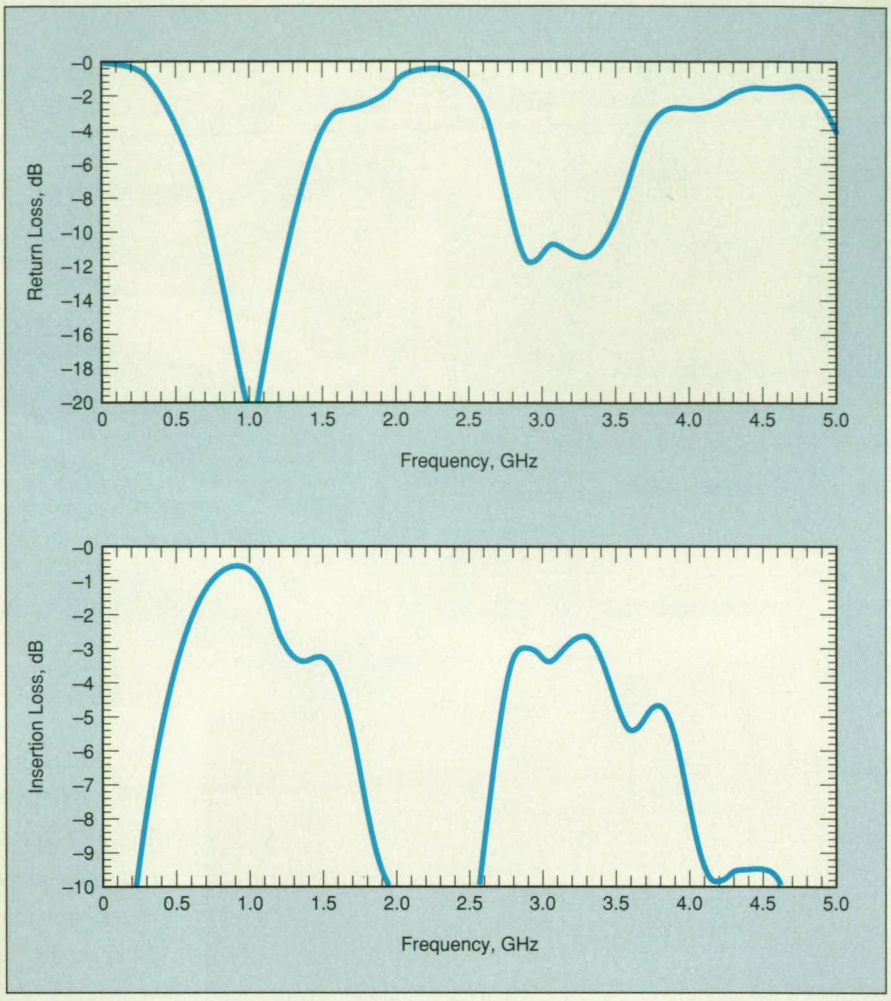


Figure 2. **Return and Insertion Losses** vs. frequency were calculated by a finite-difference time-domain method for the design described in the text.

through fifth metal layers, with characteristic impedance $Z_{0s}$.

The main advantage of this device lies in its purely planar geometry. Generally, interlayer stripline coupling is achieved by use of vertical probes; that is, through-the-thickness electrical interconnections, which contribute to difficulty of fabrication. The present design provides for RF coupling via the interlayer electromagnetic field, eliminating the need for vertical probes and thereby easing fabrication.

The basic configuration of the device is illustrated in Figure 1. All of the dielectric layers (not shown) between the metal layers are assumed to be of equal thickness $h$ and equal relative permittivity $\varepsilon_r$. The quarter-wavelength slots in the input and output regions of layer 3 suppress undesired components of interlayer propagation in those regions. Specific dimensions can be altered somewhat (for example, slot lengths can be made to differ slightly from a quarter wavelength) to suit specific applications, without deviating from the overall design concept.

A trial design for an operating frequency of about 1 GHz specifies the following parameters:

- $h$ = 0.125 in. = 3.175 mm
- $w_s$ = 7 mm
- $w_p$ = 15 mm
- $L$ = 60 mm
- $t$ = 15 mm
- $\varepsilon_r$ = 1.1
- $Z_{0s}$ = 61 Ω
- $Z_{0p}$ = 60 Ω

Figure 2 shows return and insertion losses calculated for this design.

*This work was done by Ann N. Tulintseff of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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*Refer to NPO-20115, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# Circuit for Automatic Tunneling-Controlled Golay Cell

## Features include low noise, high gain, and low power consumption.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

An automatic tunneling-controlled, micromachined Golay cell has been implemented in a multichip integrated-circuit module. The module is designed specifically for sensing infrared radiation indicative of the concentration of glucose in blood, but its low noise, high gain, and low power consumption also make it attractive for other infrared-sensing applications.

Numerous micromachined sensors based on the use of electronic feedback control to maintain a constant level of quantum-mechanical tunneling of electrons have been reported in *NASA Tech Briefs*. Particularly relevant was a class of Golay-cell/tunneling-device combinations described in "Micromachined Electron-Tunneling Infrared Detectors" (NPO-18413), in *Laser Tech Briefs*, Vol. 1, No. 1 (September 1993), page 20.

In the present device, the basic principle described above is exploited to measure the pressure on a membrane of a micromachined Golay cell. A bias voltage is applied across a small gap (about 10 Å wide) between two tunneling electrodes, of which one is the membrane in question coated with metal and the other is a tunneling tip. The bias voltage gives rise to a quantum-mechanical-tunneling current of electrons between these electrodes, and the magnitude of this current depends on the size of the gap.

The distance between the membrane and the tunneling tip is controlled by applying a control voltage to an electrostatic-deflection electrode. The circuit adjusts the control voltage to counteract any deviation of the tunneling current from a preset value and thereby maintain the desired constant gap of about 10 Å. The feedback loop that generates the control voltage includes a long-time-constant integrator, the output of which controls the current through a transistor. The voltage drop of this current through a resistor governs the voltage applied to the electrostatic-deflection electrode. The control voltage is a measure of the force needed to prevent deflection of the membrane from the desired constant gap and is thus a measure of the pressure of gas on the membrane, as affected by absorption of infrared radiation in the gas according to the classical Golay-cell principle.

*This work was done by Vardkes Victor Boyadzhyan-Sevak of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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*Refer to NPO-20035, volume and number of this* NASA Tech Briefs *issue, and the page number.*

## Software for Operating a Forward-Link-Simulator Card

A computer program has been developed to serve as the means for setting up, controlling, and receiving information on the status of a forward-link-simulator card in a Digital Equipment Corporation (DEC) Alpha computer that runs the Digital UNIX operating system. The program performs functions of both a device driver and an application-program interface (API).

Some definitions of terms are prerequisite to a meaningful description of this development. "Link" as used here signifies a radio communication link that conveys digital data and command signals between an Earth station and a spacecraft. A forward or a return signal link in this context is an Earth-to-spacecraft or a spacecraft-to-Earth link, respectively. "Card" as used here signifies a printed-circuit board that holds special-purpose electronic circuitry. "Device-driver" as used here signifies software — typically at the lowest level — that communicates directly with the circuitry.

Before this program became available, there was no Digital UNIX driver or API software for the forward-link-simulator card. It was necessary to operate the forward-link-simulator card by use of the Digital UNIX driver software for another card — the return-link processor card (RLPC) that is functionally different, has a different address map, and has no reading or writing interface. The API software used previously was based on Windows NT API calls, which contain Windows-NT-specific code that does not work in UNIX. For transferring data, the Windows NT code does not use direct memory access (DMA) and instead uses slower memory moves. There are no reading- or writing-interface components in either the Windows NT API or the Digital UNIX RLPC-driver software used previously.

The present program is written in the C computing language. The driver portion, called "fwlc.mod," performs the system and low-level functions of an interface to the forward-link-simulator card. In the development of the API portion, Windows NT system code was removed and replaced and reading and writing interface code and a DMA transfer capability were added. Called "apiLib.a," the API portion contains function calls that increase the functionality of the card and implements a threaded DMA transfer.

In comparison with the previous RLPC-driver software, the driver component of the present software implements a simpler and more classical approach. As a result, the present software is more portable and application programs that use the driver component can be executed in user mode rather than in kernel (privileged) mode.

*This work was done by David Fisher of Stinger Ghaffarian Technology and Robert Kuntz of RMS for* **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
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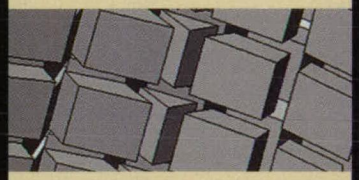

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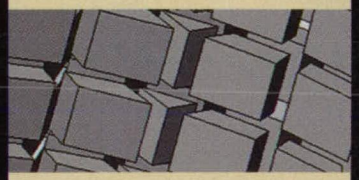

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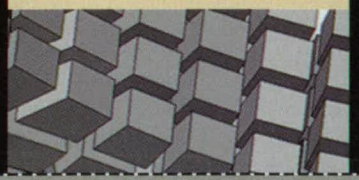

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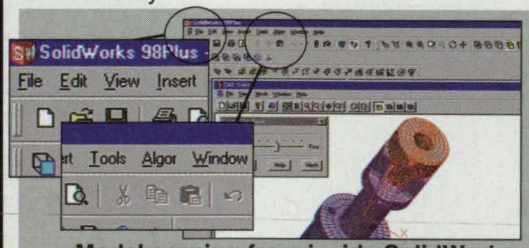
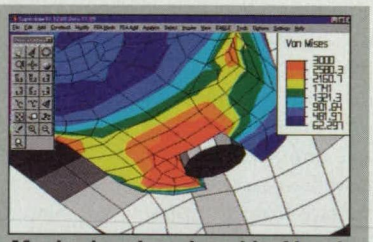



**Model running from inside SolidWorks (typical)**

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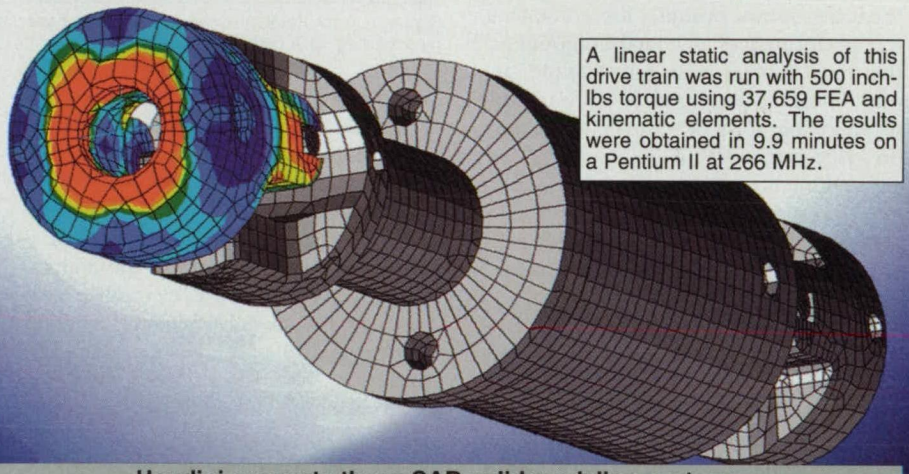

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# Electric-Arc and Electrochemical Texturing of Surfaces

## Potential applications include x-ray-tube anodes and orthopedic implants.

*Lewis Research Center, Cleveland, Ohio*

Electric arcs and electrochemical etching can be used to impart microscopic textures to surfaces of metals. In electric-arc texturing, one strikes an arc between a water-cooled electrode and a substrate that one seeks to texture. As the arc is moved across the substrate surface, a condensate from the plasma consisting of a mix of electrode and substrate species becomes redeposited on the substrate, forming an extremely rough surface layer that is intimately mixed with, and attached to, the substrate. The thermal emittances of arc-textured surfaces are considerably greater than those of the corresponding untreated surfaces. Unlike high-thermal-emittance oxide coatings, arc-textured surfaces are integral with substrates and are thus less likely to spall because of differential thermal expansion over wide ranges of operating temperatures. Arc texturing shows promise for enhancing the performances of metal components that must radiate heat; for example, anodes of x-ray tubes used in computer-assisted tomography, or waste-heat radiators on spacecraft.

Experiments in arc texturing were performed using (1) substrates made of various elemental metals and metal alloys; (2) electrodes made of carbon or silicon carbide; and (3) various arc currents, both dc and ac. The carbon electrodes were operated in argon; the silicon carbide electrodes were operated in air. Initial tests showed that ac arcs yielded higher emittances; thereafter, all texturing was done with sinusoidal-waveform ac arcs at (1) currents from 14 to 20 A with frequencies from 100 to 1,000 Hz in the case of carbon electrodes and (2) currents of 15 A with a frequency of 60 Hz in the case of silicon carbide electrodes. Figure 1 shows the increases in total hemispherical emittances of various alloy substrates, both untreated and treated by carbon-arc texturing.

In electrochemical texturing, a substrate is connected as the positive electrode in an electrochemical cell, and during operation of the cell, the electrolyte is agitated. The result of this process is a random distribution of electrochemically etched pits produced on the substrate surface. Experiments in electrochemical texturing were performed on substrate rods of the alloy Ti/6Al/4V (numbers indicate weight percentages, with balance of Ti), using an aqueous solution of sodium chloride as the electrolyte. The electrolyte was agitated by an ultrasonic-bath apparatus; the stainless-steel wall of the apparatus both contained the electrolyte and served as the negative electrode of the electrochemical cell. The agitation of the electrolyte assisted in the removal of oxides forming on the surfaces of the rods.

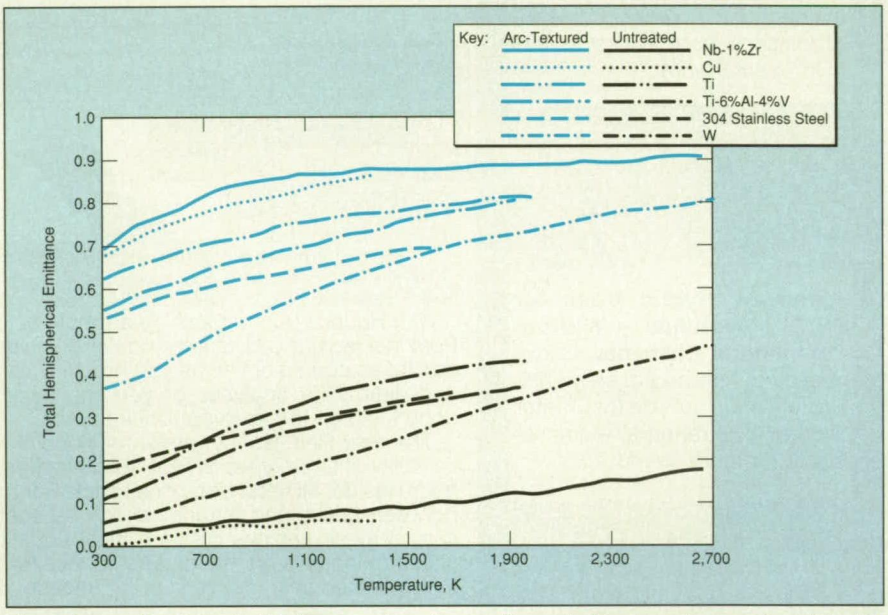


Figure 1. **Total Hemispherical Emittances** of specimens of several alloys were increased considerably by texturing with carbon arcs.

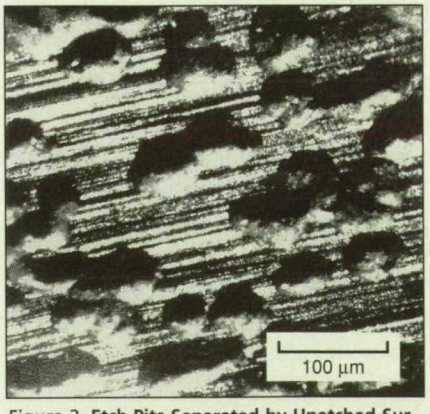


Figure 2. **Etch Pits Separated by Unetched Surface** are clearly visible in this optical micrograph of specimen of electrochemically textured Ti/6Al/4V.

In each experiment, only the end face of the rod was exposed, at a current density of 4.2 A/cm². The resulting erosion took the form of approximately hemispherical etch pits, with diameters of about 50 µm, randomly separated by unetched metal surface areas (see Figure 2).

The sizes and density of the etched pits could be tailored to favor the in-growth of bone on the stems of an orthopedic implant. Because there would be no buildup of material on surface areas between etch pits, the outside dimensions of the orthopedic- implant stems would be unaffected by the electrochemical texturing. Thus, use of electrochemical texturing would not make it necessary to alter the dimensions of orthopedic implants.

*This work was done by Bruce A. Banks and Sharon K. Rutledge of* **Lewis Research Center** *and Scott A. Snyder of Ohio Aerospace Institute. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

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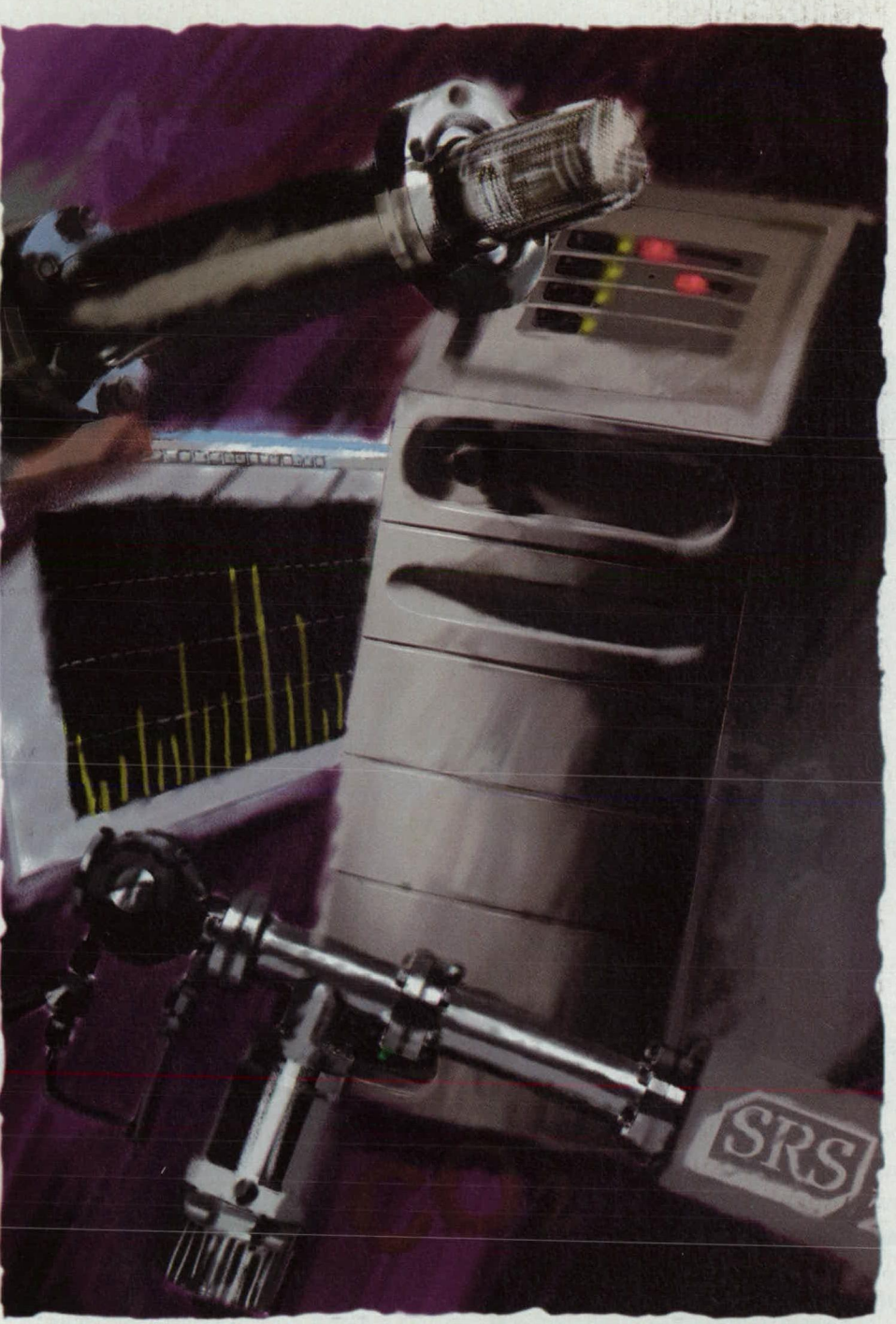
# The Art of Gas Analysis



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# Improved Fabrication of Electrodes for Methanol Fuel Cells

**Expensive catalytic metals are utilized more efficiently.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A method of fabricating membrane electrode structures for methanol fuel cells involves, among other things, the use of improved sprayers to deposit inks containing catalytic metals on membranes of Nafion™ (or equivalent) perfluorosulfonic acid-based hydrophilic, proton-conducting ion-exchange polymer. In comparison with older methods, the present method provides for faster production with more efficient utilization of the expensive catalytic metals. The present method is thus better suited to mass production.

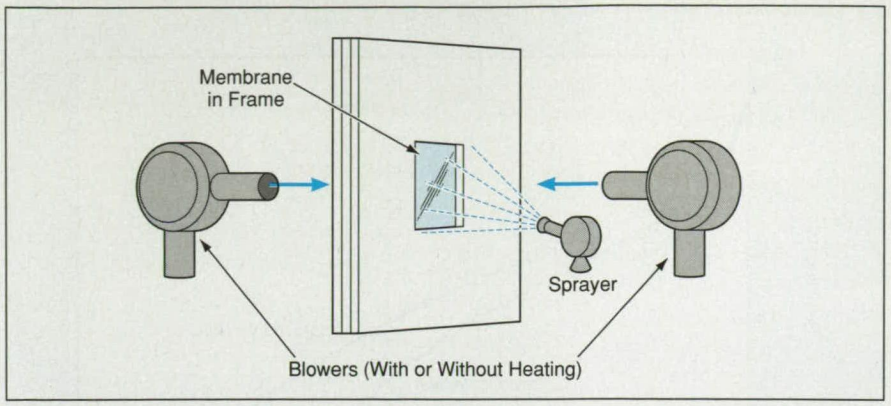
The older methods do not provide for deposition of uniformly thin catalytic layers on membranes, nor do they afford the flexibility of depositing well-defined multiple thin catalytic layers of different compositions. The present method does provide these capabilities, thus making it possible to tailor catalytic layers more precisely to achieve comparable cell performances with reduced catalyst loadings. The improved sprayers used in the present method contribute to the attainment of these objectives in that they produce slow, fine sprays that can be aimed more precisely on the surface areas to be coated, without wasting sprays on adjacent areas. Moreover, whereas the sprayers used in the older methods frequently became clogged, the improved sprayers are designed to prevent clogging.

The catalytic ink usually comprises the catalytic metal (Pt for the cathode or a mixture of Pt and Ru for the anode), a Nafion™ (or equivalent) ionomer solution, water, and isopropanol, with perhaps a small amount of a polytetrafluoroethylene-based additive. The ingredients of the ink are mixed well by use of ultrasound, and the viscosity of the ink is adjusted, by addition of small amounts of water and isopropanol, to enhance sprayability. The ink is then transferred to the sprayer.

In fabricating a membrane electrode according to the present method, the membrane is first conditioned in water, then soaked in an aqueous solution of isopropanol or methanol; this soaking is necessary to swell the membrane to prevent wrinkling that would otherwise occur when the sprayed catalytic ink subsequently comes into contact with the membrane. The membrane is then mounted in a frame (see figure), which must be nonmetallic to prevent corrosion. Then before the membrane dries out, it is sprayed on one side with catalytic ink. The position and settings of the spray head and the rate of flow of compressed air that drives the sprayer are adjusted to regulate the characteristics of the spray to ensure that the spray does not dry out on its way to the membrane and so that the deposited material bonds to the membrane and forms an electrochemically active surface. The spray-coated membrane is then dried with air at ambient temperature or, optionally, air heated to a temperature between 40 and 60 °C to accelerate drying.

Additional coats of catalytic ink on the same side or on opposite sides can be applied by repeating the spraying and drying steps. Preferably, the layers are applied alternately on the anode and cathode sides to minimize any stresses remaining after the coating process. The areal mass density of a single coat can be as small as 0.1 mg/cm$^2$.

Upon completion of coating, the membrane is released from the frame and hot-pressed between anode- and cathode-side carbon-paper supports. The resulting




The **Membrane Is Sprayed and Dried** in the frame, which helps to maintain its dimensions and shape. Spraying and drying conditions are adjusted to obtain an adherent deposit of catalytic material, without cracking of the deposit or excessive residual stress in the membrane.

sandwich electrode structure is then stored in water until use.

In experiments, the performances of fuel cells containing electrode structures made by the present method were found to be comparable to those of fuel cells containing electrode structures made by older methods. However, the amounts of catalysts used in the present method ranged from 1 to 2 mg/cm², whereas the amounts used in the older methods were typically about 4 mg/cm². The achievement of comparable performance with less catalytic material by use of techniques suitable for mass production is a significant step toward commercialization and lowering the costs of producing fuel cells.

*This work was done by William Chun, Sekharipuram Narayanan, Barbara Jeffries-Nakamura, Thomas I. Valdez, and Juergen Linke of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free online at www.nasatech.com*** *under the Materials category.*

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# Another Improved Method for Making Fuel-Cell Electrodes

## Power densities can be increased at low catalyst loadings.

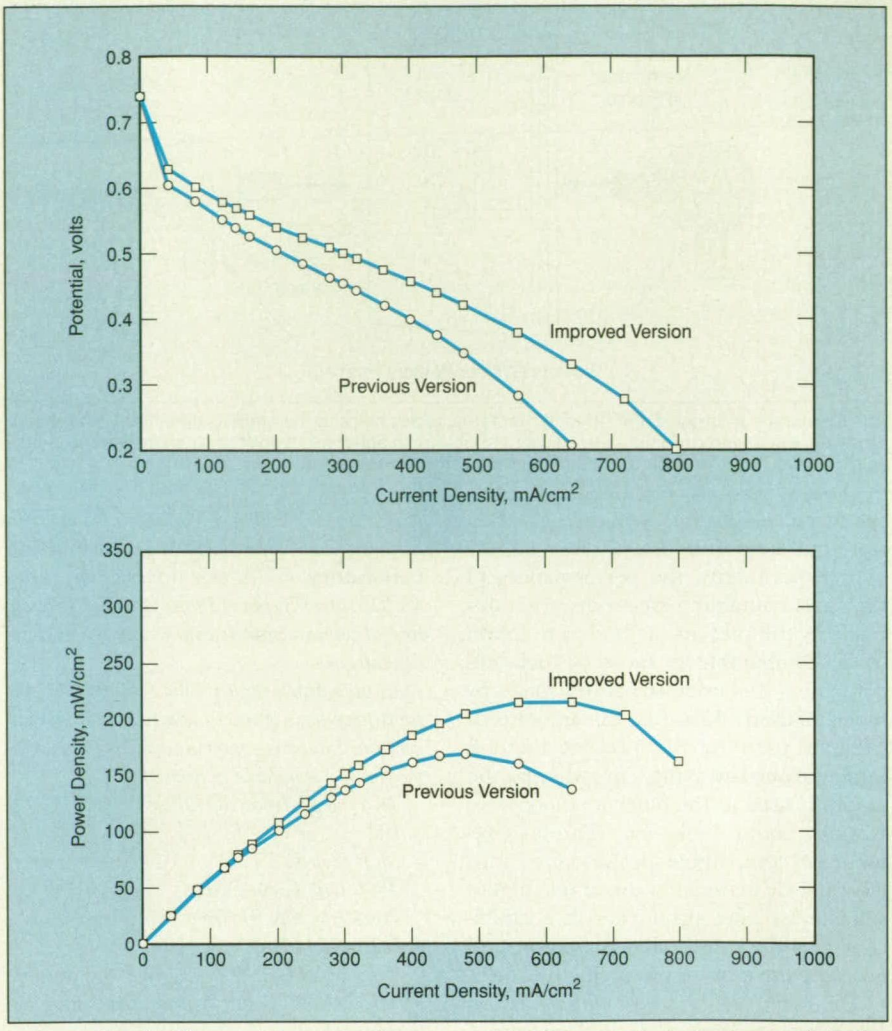
*NASA's Jet Propulsion Laboratory, Pasadena, California*

An improved method of fabricating membrane electrode structures for methanol fuel cells is similar to the method described in the preceding article, except that in this method, the catalytic ink is poured and spread onto the membrane instead of sprayed. The development of both improved methods was prompted by a need to utilize expensive catalytic material more efficiently.

Older methods of fabricating such electrode structures involve the deposition of catalysts on porous carbon paper substrates, which are then hot-pressed onto solid-electrolyte membranes. In a typical case, at least half the catalyst becomes immobilized deep within the pores of the substrate. This portion of the catalyst is not accessible for electrochemical reactions, and is not available for the formation of the desired large-area, electrochemically active interface between the catalyst-coated substrate and the membrane.

Both improved processes include pretreatment of membranes by soaking in aqueous isopropanol solutions. The benefits of this pretreatment are twofold: (1) After pretreatment, the membrane and the catalytic ink have similar solvent compositions, so that the membrane will not become wrinkled when the ink is subsequently applied; and (2) The membrane becomes very soft, so that the catalytic layer can integrate with the membrane more readily during the subsequent drying and hot-pressing steps.

As in the method described in the preceding article, the pretreated membrane is mounted in a frame. The membrane in the frame is laid down horizontally on a fine, absorbent, lint-free tissue to help




**In Terms of Both Voltage and Power Density** vs. current density, an electrode structure made by the present method performed better than did one made by a previous method.

control the rate of evaporation (as explained below) of volatile constituents (water and alcohols) of the ink to be applied next. The horizontal orientation is necessary to help ensure uniformity of the ink coating. The ink is then poured on the part of the membrane exposed in the aperture of the frame, and the ink is spread over the membrane by use of a glass rod.

Slow evaporation of the volatile constituents of the ink is necessary to obtain a crack-free catalytic coat on the membrane. Therefore, immediately after spreading of the ink, the membrane is placed in a polyethylene bag with a very small orifice for escape of the volatile constituents. After 24 to 48 hours, the coating is dry and the membrane can be taken through the hot-pressing process as in the method of the preceding article.

The performances of electrode structure made by a previous method and by the present improved method were evaluated in a laboratory fuel-cell apparatus at a temperature of 90 °C. In each case, a 1 molar aqueous methanol solution was circulated past the anode side, while air at 20 psig (gauge pressure of 14 kPa) was circulated past the anode. The measured performance of the improved version was superior; in particular, the peak power density of the improved version was 210 mW/cm², as compared to 160 mW/cm² for the previous version. Because of the greater power density, the weight of a fuel-cell stack could be reduced by about 25 percent without loss in performance.

*This work was done by William Chun, Sekharipuram Narayanan, Barbara Jeffries-Nakamura, and Thomas I. Valdez of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

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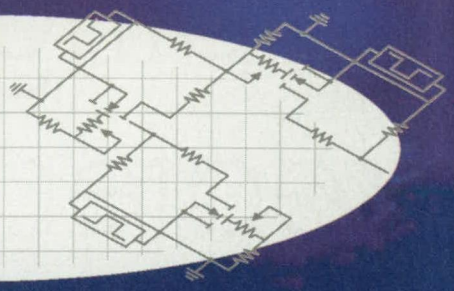


April 1999

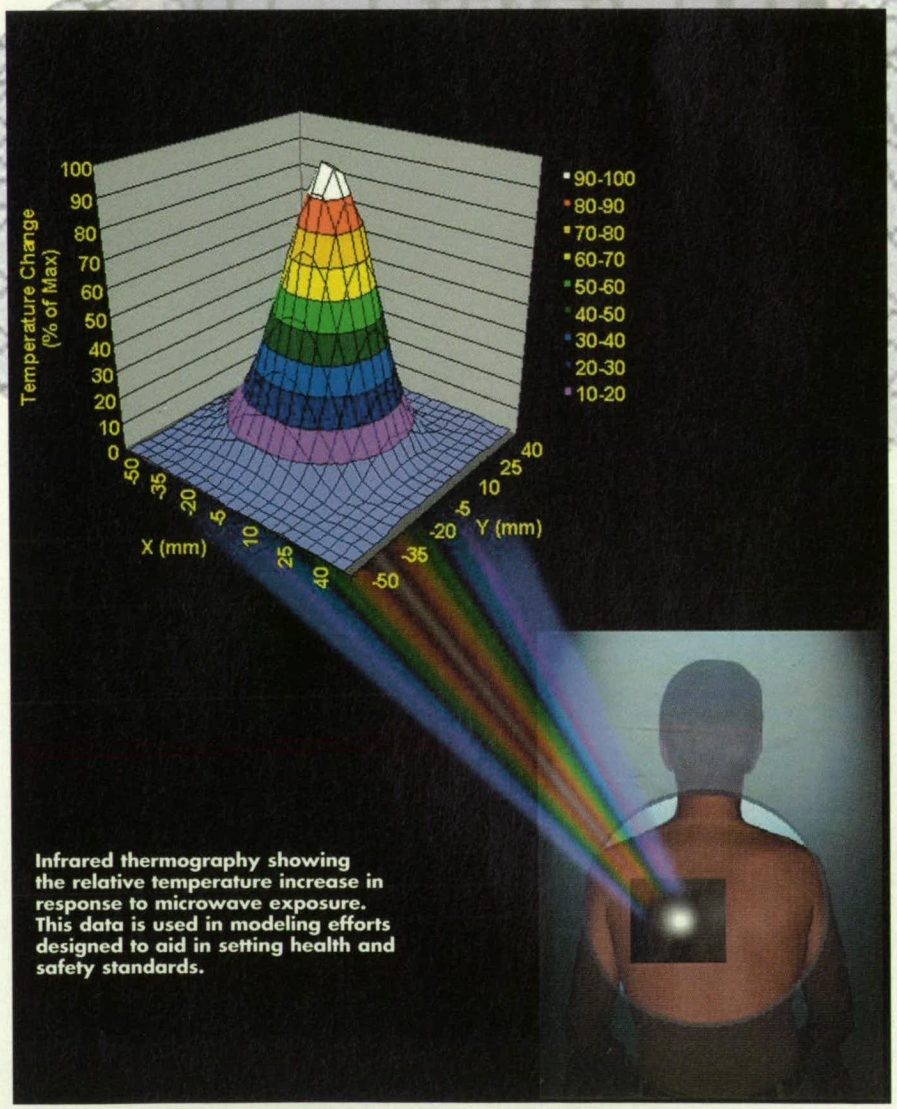
# IR Mapping for Greater Radiation Safety

## Infrared thermography is a key tool in determining safe levels of exposure to electromagnetic fields.

The U.S. Air Force, not surprisingly, is one of the world's largest developers and users of radio frequency emitting devices. And for more than 30 years the Air Force, through its Radio Frequency Radiation Branch, has led the way in studying the biological effects of electromagnetic fields (EMFs). Under the Human Effectiveness Directorate of the Air Force Research Laboratory, the branch is specifically charged with protecting Air Force and related personnel from EMF exposure dangers while minimizing negative operational impact. With the introduction of high-power microwave and ultrawideband emitters, the branch's work today is more important than ever.

Located at Brooks Air Force Base, Texas, the Radio Frequency Radiation Branch operates the world's largest, most comprehensive EMF bioeffects research laboratory.

Studying the biological effects of EMFs at the subcellular, cellular, and whole-organism levels, the branch's work covers a frequency range of 100 kHz to 300 GHz. Organizations such as NATO, IEEE, and ANSI use branch research results to help develop safety standards concerning EMF exposure levels.




**Infrared thermography showing the relative temperature increase in response to microwave exposure. This data is used in modeling efforts designed to aid in setting health and safety standards.**

### Mapping Electromagnetic Fields

Veridian, Inc., Alexandria, VA, is under contract to the Air Force to determine the bioeffects of electromagnetic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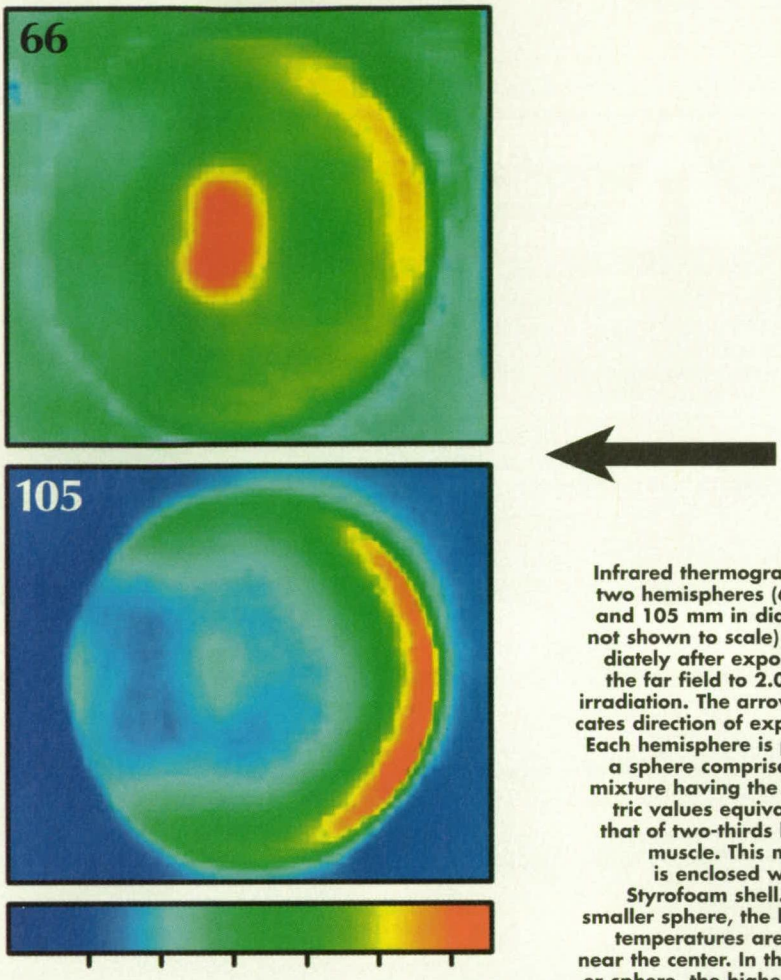


**Infrared thermography of two hemispheres (66 mm and 105 mm in diameter, not shown to scale) immediately after exposure in the far field to 2.06-GHz irradiation. The arrow indicates direction of exposure. Each hemisphere is part of a sphere comprised of a mixture having the dielectric values equivalent to that of two-thirds human muscle. This mixture is enclosed within a Styrofoam shell. In the smaller sphere, the highest temperatures are found near the center. In the larger sphere, the highest temperatures are found on the leading edge.**

fields. Veridian scientists Patrick Mason and Tom Walters, both of them PhDs working in the Radio Frequency Radiation Branch, employ "phantoms" and limited animal testing in their studies. The reusable Styrofoam-clad phantoms contain a viscous solution with dielectric properties similar to those of human body tissue, which consists of approximately two-thirds muscle. Phantoms can be as simple as spheres or blocks; they also can be shaped as small animals and full-size human bodies.

To study the effects of radio frequency radiation on a phantom or biological subject, Mason and Walters first must "map" the electromagnetic field in question. This map indicates where a test subject should be placed for optimal EMF exposure and measurement. Inside an anechoic exposure chamber, a dry, electrically conductive cloth is stretched across a screen set some distance from an EMF transmitter horn. The horn is activated and the cloth exposed. With a Raytheon Systems Company Radiance 1 portable infrared camera, incorporating a 256-×-256-pixel InSb staring focal-plane array spectrally sensitive from 3 µm to 5 µm, researchers can see in real time the EMF heating pattern generated on the cloth. Depending on the experiment, the pattern can range in diameter from a few inches to a yard or more.

By being able to view an entire EMF pattern in seconds, Walters and Mason can efficiently move through a sequence of EMF experiments. Adjustments to alter a pattern can be quickly made. But this would not necessarily be the case if the researchers employed another pattern mapping method. For example, if they used microwave dosimetry, creating a map by using a probe to determine an EMF's power density at various points, the mapping process could take hours. In addition, since an EMF consists of an almost infinite number of points, and relatively few of these could be checked with a probe, accuracy errors could be made in map creation.

Inside the anechoic exposure chamber, the tripod-mounted remote-controlled Radiance 1 camera is set up behind the EMF transmitter horn. This positioning helps prevent damage to the camera's electronics. With the Radiance 1, Mason and Walters can view the image of an EMF on a video display. Then, with a dry-erase marker they outline the EMF pattern on-screen, remove the electrically conductive cloth, and, using the marked video screen as a guide, position the test object for optimal EMF exposure. Before actual exposure, however, the researchers use the infrared camera to make one last check of the EMF pattern. While the Styrofoam material encasing test phantoms is generally thought not to interact with or influence electromagnetic fields, at times the material does. Walters and Mason make last-minute adjustments to the EMF or object placement when needed.

With the temperature of the solution inside a test phantom equilibrated to the anechoic-exposure chamber temperature, the phantom is then exposed to an EMF. Exposure times can range from seconds to hours. But since the researchers are highly concerned with determining specific absorption rate (SAR) — the rate of electromagnetic energy absorption by human tissue — exposure times typically are around 10 to 15 seconds. Longer times can result in heat transfer and heat dissipation levels that prevent accurate determination of SAR values.

Mason and Walters ascertain test-phantom temperature changes in various ways. One method involves the use of non-perturbing temperature probes placed on the surface of or inserted inside a test phantom. Yet while these provide highly accurate temperature readings, they gather only point measurements. This makes obtaining accurate overall temperature readings for a phantom extremely difficult.

With the Radiance 1 camera, however, Walters and Mason can image a phantom immediately after EMF exposure and instantly obtain an accurate temperature value for each image pixel. This allows magnitudes more of temperature data to be gathered when compared to a point-measurement method. Phantoms can even be disassembled, for instance, separating a sphere into halves, and internal temperatures determined with the camera.

To initially process captured data, the researchers use Raytheon's ImageDesk, a Windows-based thermographic analysis package that offers functions that include time vs. temperature, histogram analysis, line profiles, and image subtraction. Temperature data is exported from ImageDesk to Microsoft Excel, where the data is catalogued and manip-

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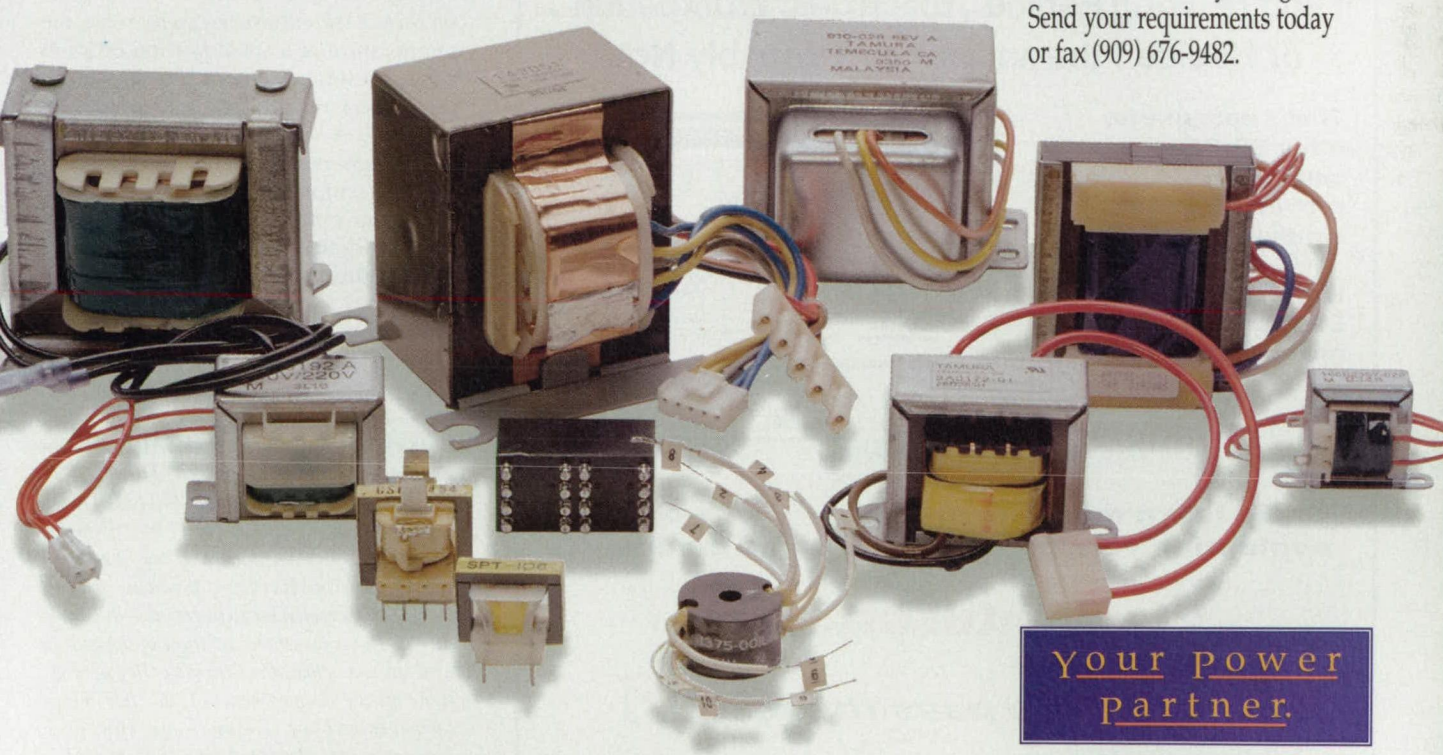

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ulated to create "maps," such as surface or topographical plots, representing EMF exposure-caused temperature changes. Temperature data also can be configured to create Apple QuickTime-format "movies," allowing researchers to view temperature change sequences on a computer monitor.

## Results of EMF Exposure Research

In their EMF exposure research to date, Mason and Walters have shown that thermal responses are the only negative biological effect of EMF exposure. The researchers emphasize that these responses would occur only as a result of exposure to very high levels of electromagnetic radiation. They also point out that U.S. Air Force studies have never revealed any link between EMF exposure and various types of cancer.

Walters and Mason have found that by taking exposure data captured via IR thermography and coupling it with finite-difference time-domain computer models, they are now able to understand in detail the localized effects of EMF exposure. In years past, scientists used whole-body SAR values to ascertain the amount of energy absorbed during EMF exposure. But researchers have come to realize that whole-body SAR values, determined by placing a test subject in a calorimeter, may paint an incomplete picture. EMF exposure can increase the temperature of a small portion of a test subject several degrees while the rest of the subject remains at its original temperature. A whole-body SAR measurement might not detect that local change. Yet that temperature increase may ultimately have an impact on the test subject as a whole. Mason and Walters point out that through instruments such as the Radiance 1 camera, infrared thermography has become an indispensable tool in EMF exposure research.

*For more information on Veridian Inc. work on electromagnetic fields, contact Patrick A. Mason, PhD, USAF/AFRL—Veridian Engineering, 8315 Hawks Rd., Brooks AFB, TX; 78235-5324; (210) 536-2362; fax: (210) 536-5174; E-mail: patrick.mason@aloer.brooks.af.mil. For more information on Raytheon products, contact Raytheon Commercial Infrared at 1-800-990-3275. Views presented are those of the author and do not reflect the official policy or position of the Department of the Air Force, Department of Defense or the U.S. Government. Trade names of materials and/or products of commercial or nongovernment organizations are cited as needed for precision. These citations do not constitute official endorsement or approval of the use of such commercial materials and/or products.*

# $In_xGa_{1-x}P/In_xGa_{1-x}As$-on-Ge Solar Photovoltaic Cells

## Energy-conversion efficiencies are expected to exceed those of other known solar cells.

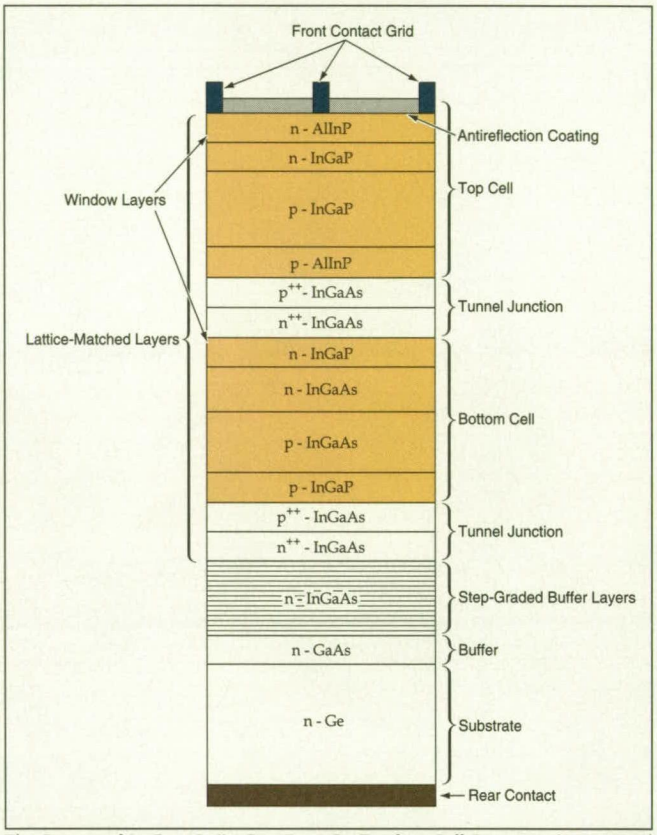
*Lewis Research Center, Cleveland, Ohio*

Monolithic, tandem two-junction $In_xGa_{1-x}P/In_xGa_{1-x}As$-on-Ge solar photovoltaic cells are being developed. The cells are designed to be used with solar concentrators to generate electric power aboard spacecraft. The theoretically achievable energy-conversion efficiency of these cells under air-mass-zero (AM0) conditions and 10× concentrated solar illumination is about 33 percent. In comparison with other known dual-junction photovoltaic cells, the proposed cells would feature highest conversion efficiency and the highest specific power. The cost per unit of power of these cells would be less than the costs per unit power of GaAs and InGaP/GaAs cells. With modifications, the cells might offer similar advantages in terrestrial applications.

To approach the theoretical efficiency, it is necessary to configure a tandem cell with an optimal combination of bandgaps. In the present case, this translates to putting the $In_xGa_{1-x}P$ cell (which has a bandgap of 1.65 to 1.7 eV) on top and the $In_xGa_{1-x}As$ cell (which has a bandgap of about 1.1 eV) on the bottom. Although the $In_xGa_{1-x}As$ and $In_xGa_{1-x}P$ are lattice-matched to each other, they are lattice-mismatched to all available substrate materials. Heretofore, the lack of a lattice-matched substrate material has impeded the realization of tandem cells with optimal bandgaps.

The approach taken in the present development effort is to form the tandem cell structure on a Ge substrate by organometallic vapor-phase epitaxy (OMVPE), using a lattice-grading technique to overcome the lattice mismatch. In addition, Ge offers the advantage of being inexpensive and rugged.

The figure depicts the proposed cell structure. The first layer deposited on the Ge substrate would be a buffer layer of GaAs, which is lattice-matched to Ge. Then a stack of $In_xGa_{1-x}As$ layers with increasing In contents would be deposited. The final InGaAs layer would have a total In content of about 23 atomic percent, as needed to obtain a bandgap of 1.1 eV for the lower cell. The subsequent lattice-matched layers (deposited without additional buffer layers) would include (1) $In_xGa_{1-x}As$ tunnel-junction layers, $In_xGa_{1-x}As$ layers of the bottom cell, more tunnel-junction layers, an AlInP window layer (bandgap 2.1 eV), $In_xGa_{1-x}P$ layers for the top cell, and a top window layer of AlInP. An antireflection coating and a contact grid would be applied to the top window layer, and a contact layer would be formed on the bottom of the substrate.




The **Proposed $In_xGa_{1-x}As/In_xGa_{1-x}P$-on-Ge Tandem Cell Structure** is expected to afford unprecedented 1-Sun AM0 energy-conversion efficiency as high as 33 percent.

Because of limitations of time and short-term unavailability of Ge substrates, GaAs substrates were used in initial experiments on the feasibility of OMVPE deposition of lattice-mismatched $In_xGa_{1-x}As$. The experiments proved successful in that the uppermost $In_xGa_{1-x}As$ layers had the desired 1.1-eV bandgaps and the densities of dislocations in these layers were below the detection limit of transmission electron microscopy ($10^7/cm^2$).

For other experiments to demonstrate the feasibility of the lower-cell design and part of the upper-cell design, $In_xGa_{1-x}As$ cells with $In_xGa_{1-x}P$ window layers, without antireflection coatings, and with 19-percent front grid coverage, were fabricated on GaAs substrates. In the experiments, the best of these cells, with bandgaps

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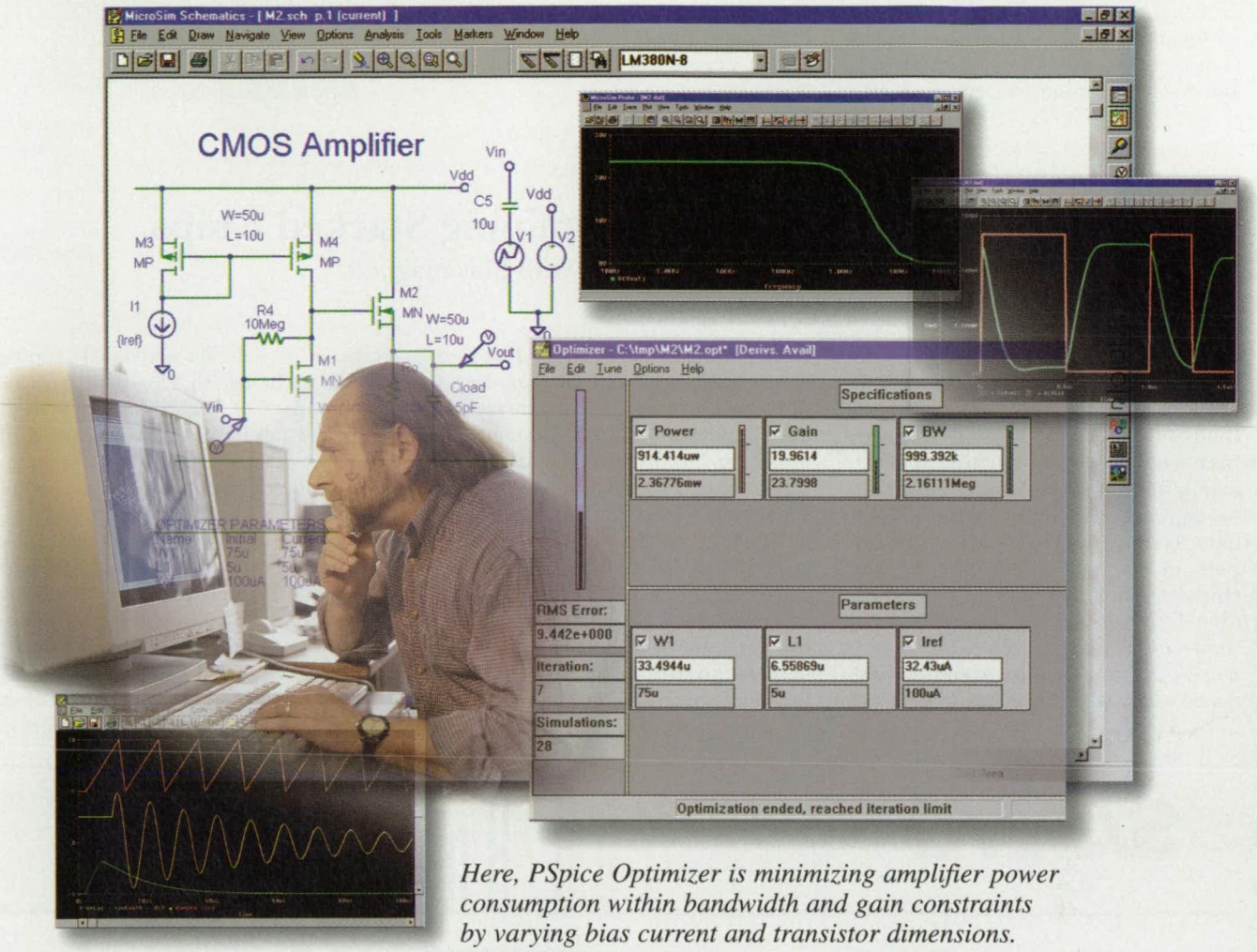


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of 1.07 and 1.15 eV, exhibited AM0 conversion efficiencies of 10.94 and 11.5 percent, respectively under 1-Sun illumination, and about 12.5 percent under 10-Sun illumination. Estimation of the effects of including antireflection coatings and reducing front grid coverage to a typical value of 5 percent leads to extrapolated 1-Sun AM0 conversion efficiencies of 17.5 and 18.4 percent, respectively. These efficiencies are almost as good as the 1-Sun AM0 efficiencies (about 20 percent) of the best Si cells.

*This work was done by Richard W. Hoffman, Jr., Mark A. Stan, and Navid Fatemi of Essential Research, Inc., for* **Lewis Research Center**. *No further documentation is available.*

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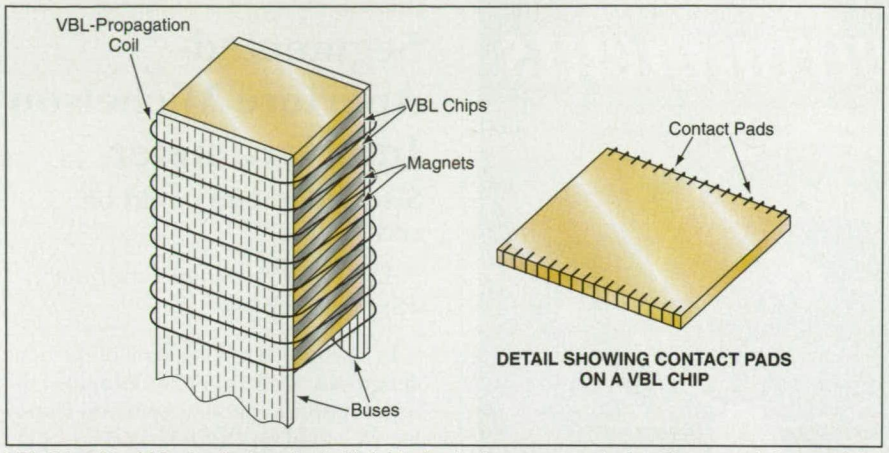
# Vertical-Bloch-Line Memories Containing Stacked Chips

## VBL memory chips would be stacked in alternation with bias magnets.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Vertical-Bloch-line (VBL) memory devices of a proposed type would include stacks of VBL memory chips plus other components (see figure on next page). Each chip would be square, approximately 15 mm on each side. Each chip would have two input/output (I/O) lines connected to 16 I/O pads on each of two opposite edges. All the chips in a stack would be oriented with their I/O pads on the same two opposite faces of the stack. Buses for connection to external circuitry would be positioned to cross the chip edges on these two faces, making contact with the I/O pads.

As specified in a preliminary design, the core of each VBL memory chip would comprise 512 VBL storage loops with 2,048 bits per loop. Thus, each chip could store 512 × 2,048 = 1,048,576 bits. The storage loops would be embodied by stripe domains stabilized in main grooves 5 μm wide and 1.25 μm deep in a garnet substrate. The bits would be embodied by VBL pairs in the walls of the stripe domains and would be stabilized by grooves 5 μm wide and 0.125 μm deep perpendicular to the main grooves. This design would make it possible to exchange 16 32-bit data with the core in parallel. With refinements in design and fabrication involving primarily the use of readily available 2-μm magnetic-bubble material and narrower features (viz., storage loops and I/O lines 2 μm wide and bit grooves 0.5 μm wide), the storage capacity of a chip of the same size could be increased to about 25 Mb. Then using submicron lithography when the 0.5-μm magnetic-bubble material now undergoing development becomes available, it should be possible to increase




**VBL Chips Would Be Stacked** to obtain high bit density in a memory device. The general design of devices like this one reflects consideration of manufacturability, yield, biasing, driving, and packaging.

the capacity to about 400 Mb per chip.

In addition to I/O drive currents supplied via I/O pads, operation of a VBL chip depends on two spatially uniform magnetic fields perpendicular to the chip plane: a dc magnetic bias field and field oscillating at a frequency of several megahertz for VBL propagation. In a device as proposed, the dc magnetic bias fields would be provided by permanent-magnet plates between the chips and at the ends of each stack. The high-frequency VBL-propagation magnetic field would be generated by use of a coil surrounding the stack.

Nonuniformity in the dc magnetic field at the ends of the stack could be reduced to acceptable levels by stacking more magnets at the ends, thickening the end magnets, using high-permeability equalizer plates, bevelling the edges of the magnets to reduce edge fields, and/or the use of a high-permeability sheet housing that would both perform the function of a conventional magnet yoke and act as a shield against externally generated magnetic-field disturbances. The number of windings in the VBL-propagation coil must be large enough to keep the nonuniformity of its magnetic field acceptably small, but not so large that the resulting inductance would be excessive at the operating frequency. The optimum winding density would probably be about 1 turn per chip, except at the ends, where the winding density would have to be doubled to prevent excessive nonuniformity of the magnetic field.

*This work was done by Udo Lieneweg of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

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# Segmented-Aperture Michelson Interferometer

## Size and weight could be reduced.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

In a proposed modification of the basic design of a Michelson interferometer, the beam aperture would be split into a number ($N \geq 2$) of smaller areas and the optics arranged so that the beam in each area would generate a distinct segment of the overall desired interferogram. Each segment of the interferogram would correspond to a different segment of the overall optical-path difference (OPD) needed to obtain the desired spectral resolution. As explained below, the advantage of the proposed modification is that the size and mass of a Michelson interferometer could be reduced considerably.

In a traditional Michelson interferometer, it is necessary to move one mirror a distance $x/2$ to obtain an OPD of $x$. If the beam is split into $N$ smaller beams, each generating a different part of the interferogram, then the same overall OPD is obtained by moving the mirror a much smaller distance — only $x/2N$. The moving-mirror arm is a major contributor to the volume, mass, and mechanical complexity of a Michelson interferometer; reducing the overall required mirror travel would make it possible to use smaller, simpler mirror-support structures and mirror-translation mechanisms.

According to tradition, the design of an interferometer must provide for a single beam area, wherein the beam is modulated by a single set of interferometer mirrors. Traditional thinking on this subject has been dominated by the assumption that continuity of the interferogram must be maintained. The proposed modification would violate the traditional requirement of continuity. The violation is justified by the realization that the requirement of continuity is not based on fundamental physics; provided that one can find a way to splice the segments together seamlessly into one interferogram, there is no physical reason to refrain from use of a segmented aperture.

The $N$ segments of an interferogram would be collected in one mirror stroke and would be digitized. The requirement for seamless splicing of the segments translates to a requirement to sample all of the segments on the same computational grid and to match their

amplitudes. For this purpose, it would likely be necessary to oversample each segment on its own grid, then digitally resample it to place it on the same grid as that of the adjacent segment. The segments would be adjusted accordingly by comparing small regions of overlap between them and compensating for differences in sampling, signal amplitude, and offset. After adjustment, the segments could be spliced together to form the full interferogram, which could then be Fourier-transformed in the normal way.

Of course, segmentation of the interferometer would entail some engineering compromises. The decrease in overall size, mass, and mechanical complexity would be partly counteracted by a corresponding increase in the number of photodetectors and associated signal-processing circuits, by the need to prevent optical cross-talk between segments, and by an increase in the complexity of computations needed to process the signal-chain outputs. Fortunately, most of these considerations could be addressed by use of modern electronic signal-processing and computing equipment. Recent advances in electronics have yielded great increases in performance and decreases in size and power consumption.

*This work was done by Michael Eastwood and Crofton Farmer of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category. NPO-20346*

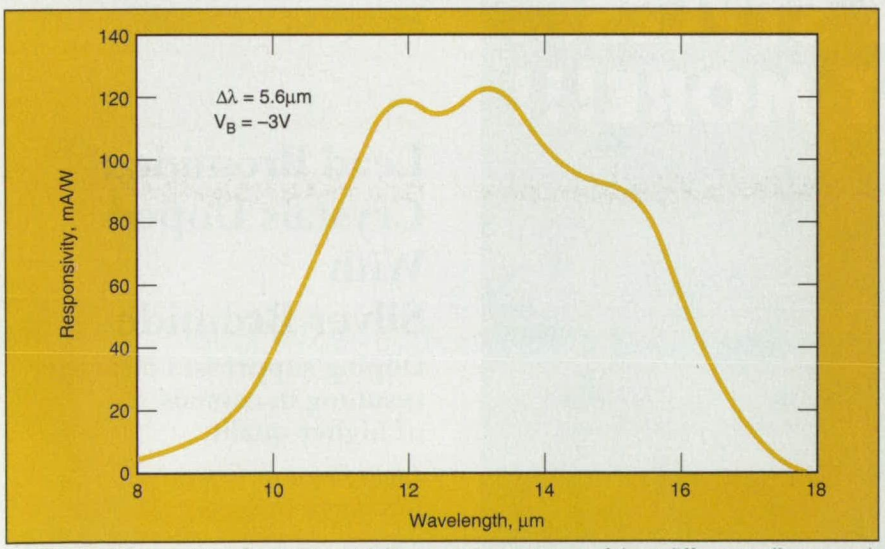
# Broad-Band GaAs/$Al_xGa_{1-x}As$ QWIPs

## Quantum wells designed for different pass bands are stacked in repeating sequences.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

GaAs/$Al_xGa_{1-x}As$ quantum-well infrared photodetectors (QWIPs) with broad-band responses are undergoing development. The broad-band responses are obtained by varying the depths and widths of the wells and the thicknesses of the barriers between the wells, as explained below.

Typically, a QWIP is of the bound-to-continuum or the bound-to-quasi-bound type. In the bound-to-continuum type, quantum state of one of the wells. The excited electron can escape from the well and, if a suitable bias voltage is applied, then many such photoelectrons are collected as photocurrent.




**The Spectral Responsivity of a QWIP** containing repeating sequence of three different wells was much broader than that of a typical older QWIP containing multiple identical wells.

A GaAs/$Al_xGa_{1-x}As$ QWIP contains layers of GaAs (the wells) alternating with layers of $AlxGa_{1-x}As$ ($0<_x<1$) (the barriers). Detection of a photon in a QWIP involves photoexcitation of electrons from the ground to the first excited the first excited state lies above the top of the well. In the bound-to-quasi-bound type, the first excited state lies exactly at the top of the well. Each of these types offers a different advantage; the spectral width of photoresponse is broader in the

bound-to-continuum type, while the bound-to-quasi-bound case offers the advantage of a smaller thermionic contribution to dark current.

The height of each barrier, and thus the depth of an adjacent well, is determined by the mole fraction ($x$) of aluminum. The energy heights of ground and first excited states relative to the tops and bottoms of the wells, plus the spectral responses of QWIPs, are determined by the widths of the wells, the thicknesses and heights of the barriers, and the well-doping densities. These thicknesses and compositions can be chosen by design and implemented with established deposition techniques.

In a typical bound-to-quasi-bound QWIP of older design, all of the wells are of the same width and doping density, and all of the barriers are of the same thickness and the same aluminum content. The spectral width of its photoresponse is about 10 percent of its peak-response wavelength, which can be set at a value between 6 and 20 μm by suitable choice of layer thicknesses and $x$.

A device with broader spectral response can be constructed by stacking different quantum wells in a repeating sequence. Each sequence contains several quantum wells; the thicknesses and compositions of the barrier and well layers within each sequence can be tailored to optimize each well for a different pass band that partly overlaps one or more pass band(s) of the other wells in the sequence. The net effect of the multiple partial overlaps is a broader overall pass band for the QWIP device as a whole.

An experimental device of this type was made with 35 repeating three-well sequences. The wells in each sequence were designed for peak responses at wavelengths of 13.5, 14.3, and 15.5 μm, respectively. The measured spectral response of this device (see figure) was found to be about 4 times as broad as that of a typical bound-to-quasi-bound QWIP of older design for the same nominal peak wavelength.

*This work was done by Sumith Bandara and Sarath Gunapala of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Technology Reporting Office*
*JPL*
*Mail Stop 122-116*
*4800 Oak Grove Drive*
*Pasadena, CA 91109*
*(818) 354-2240*

*Refer to NPO-20319, volume and number of this* NASA Tech Briefs *issue, and the page number.*



## Lead Bromide Crystals Doped With Silver Bromide

### Doping suppresses cleavage, resulting in crystals of higher quality.

*Lewis Research Center, Cleveland, Ohio*

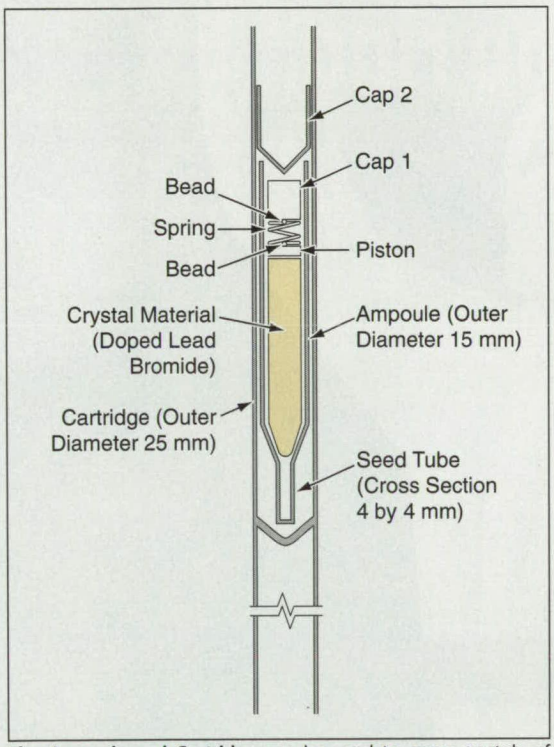
Doping with silver bromide has been found to be an effective technique for enhancing the optical homogeneity and other qualities of single crystals of lead bromide. These crystals are grown from melts by directional solidification. The doping suppresses cleavage that would otherwise occur during cooling after directional solidification.

Like other lead halides, silver bromide is potentially useful in acousto-optical and photoluminescent devices; the combination of optical and acoustical properties of the lead halides may be particularly suitable for extending the performances of optical signal-processing systems. Lead halides exhibit very high acousto-optical figures of merit; for example, the acousto-optical figure of merit of lead bromide is about 550 times that of quartz. Lead halides also exhibit a transparency range wider than that of most other commercially available materials that could be used for the same purposes.

To realize the full potential of lead halides, it is necessary to grow high-quality crystals without cracks. In the case of highly pure lead bromide, a second-order solid-state phase transformation occurs near the melting temperature during cooling after growth of a crystal from a melt. This phase transition changes the symmetry of the crystal, evolves a large amount of energy, and is associated with a disordering reaction. The resulting stress is large enough to cleave the crystal.

Doping with silver bromide reduces the energy of the phase transformation and thereby reduces the stress, making it possible to grow a crystal of better optical quality. Experiments have shown that doping to a level between 300 and 1,500 parts per million (ppm) is sufficient to prevent both microcracking and cleavage. Further experiments have shown that doping to a level as high as 3,500 ppm does not change acoustical or optical properties.

The figure illustrates a quartz ampoule and cartridge designed to ensure proper seeding and vacuum conditions during growth of a crystal of doped lead bromide by the Bridgman directional-solidification technique. The top of the ampoule is sealed into the cartridge with cap 2. The bottom of the ampoule tapers down to a seed tube. Cap 1 seals the vacuum in the ampoule. To keep the melt in contact with the seed in the microgravity environment or in a tilted orientation in normal gravity, a spring pushes down on a quartz piston. The top and bottom ends of the spring are attached to cap 1 and the piston, respectively, via quartz beads. During the crystal growth, as the material melts and the volume changes, the spring force on the piston keeps the melt in contact with the seed.




**The Ampoule and Cartridge** can be used to grow crystals of doped lead bromide by directional solidification in normal Earth gravitation or in microgravity. The spring-loaded quartz piston keeps the melt in contact with the seed.

The directional-solidification process can be implemented by translation of either the ampoule or the furnace used to melt the doped lead bromide contents along part of the length of the ampoule. The cartridge is suitable for either implementation. The dimensions shown in the figure are typical and can be changed to grow wider or narrower crystals. The lengths of the ampoule and cartridge can similarly be chosen to fit the length of the crystal to be grown.

*This work was done by N. B. Singh, T. Henningsen, R. Mazelsky, M. Gottlieb, J. J. Conroy, R. H. Hopkins, Walter M. B. Duval, G. Santoro, Thomas E. Haley, and Ronald D. Hamacher of Westinghouse Electric Corp. for* **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Materials category.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn:*

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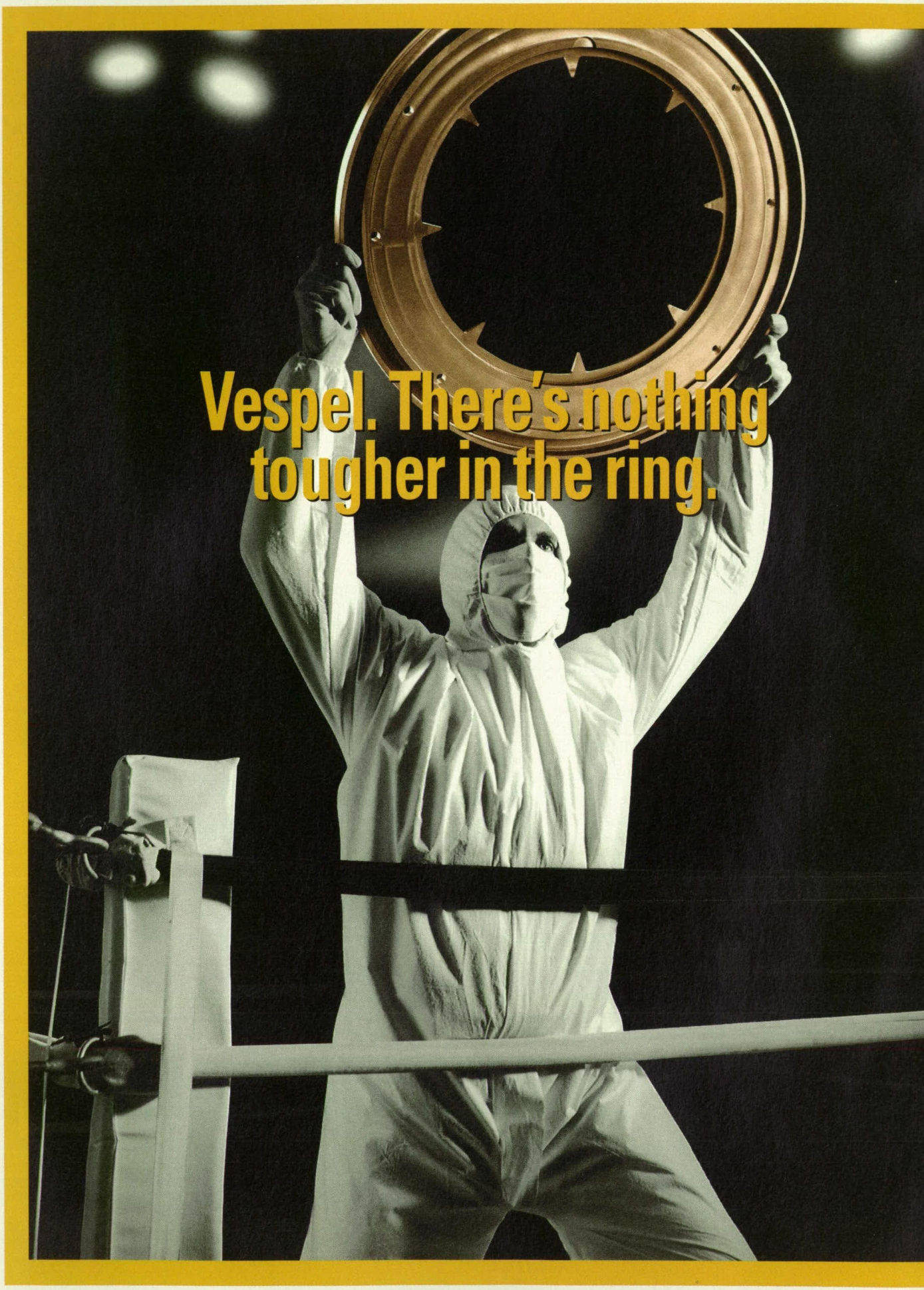
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**For More Information Circle No. 470**

# Improved Electrical Connections for Thin-Film Thermocouples

## Unlike previous connections, these withstand high test temperatures.

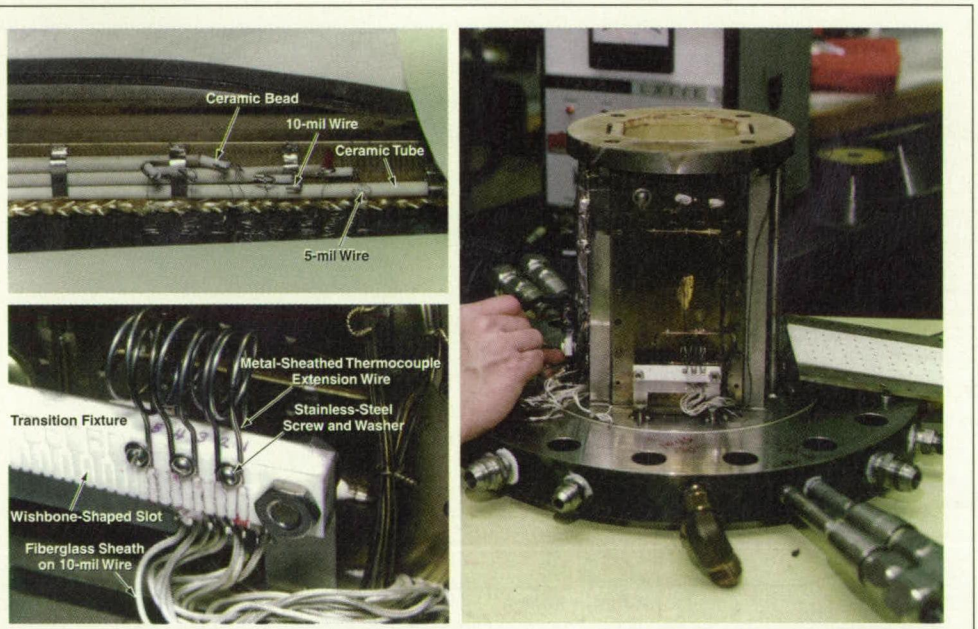
*Lewis Research Center, Cleveland, Ohio*

Improved electrical connections have been developed for thin-film thermocouples used to measure temperatures on the surfaces of ceramic-matrix composite-material specimens during high-temperature tests. In a test, specimens are arranged in a four-sided configuration in a test rig, where they are heated from inside the rig by a flame. Composite specimens have endured up to 3,200 °F (1,760 °C) on the hot sides, while temperatures at electrical connections for thermocouples have reached 1,200 °F (650 °C). Previously, the electrical connections on the thermocouples could not withstand the test temperatures; they failed so frequently that no useful data could be taken. In addition, the design of the electrical connections made it difficult to change specimens in the test rig. The improved electrical connections withstand the test temperatures and make it possible to change specimens easily.

Thin-film thermocouples were installed on specimens by sputtering. Wires with a diameter of 5 mils (0.13 mm) were attached to the thermocouples by parallel-gap welding. Each specimen was then mounted on a spring plate by use of straps made of a nickel alloy.

The figure illustrates key features of the improved electrical connections. Small ceramic tubes were strapped to the inside perimeter of the string plate. Wires with a diameter of 10 mils (0.25 mm) were run through the ceramic tubes. Starting from the outer ends of the ceramic tubes, the 10-mil wires were covered with fiberglass sheaths and run from the hot interior of the test chamber to a transition fixture (described in the next paragraph) located near the specimen, but not so close as to be subjected to the maximum test temperature. At the inner ends of the ceramic tubes, the 10-mil wires were threaded through and bent around ceramic beads and attached to the 5-mil wires. The specimen as thus prepared was ready for installation in the test chamber.

The key to interchangeability of specimens was the transition fixture, which was made from a block of machinable ceramic. Small wishbone-shaped slots were milled into the block. A metal-sheathed thermocouple extension wire was stripped back and laid into the single-slot end of each wishbone, with its leads in the branch slots at the other end of the wishbone. In each branch slot, the thermocouple extension lead was placed in contact with the outer end of the corresponding 10-mil lead from the specimen. The metal-sheathed extension wires were held in place by washers and stainless-steel screws that engaged threads tapped into the block. Electrical contact between the thermocouple leads and the 10-mil specimen leads could easily be made and broken at the transition fixture.




**Electrical Connections for Thermocouples** on a test rig withstand high temperatures. Thermocouples can readily be connected or disconnected at the transition fixture.

*This work was done by Chip Redding of* **Lewis Research Center**. *No further documentation is available.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135.*
*Refer to LEW-16688.*

# High-Performance HgCdTe Detectors for Remote Sensing: Part 1

## A split-geometry design makes it possible to satisfy several special requirements.

*Goddard Space Flight Center, Greenbelt, Maryland*

Focal-plane arrays of HgCdTe photoconductors have been designed and fabricated to satisfy special requirements for high-performance long-wavelength infrared (LWIR) photodetectors. The special requirements are the following:

- The photoconductive LWIR photodetectors must offer high response and low noise in detection of radiation at wavelengths from 9.1 to 16.6 μm.
- The electrical characteristics of the photoconductive LWIR photodetectors must include high resistance and low power dissipation.
- Each array of the photoconductive LWIR photodetectors must be buttable against another, separately manufactured array of photovoltaic devices on the same focal plane for detecting radiation at wavelengths from 7.1 to 9.1 μm.

The design features a split geometry with all electrical leads on one side of each array; this aspect of the design ensures the required buttability. Furthermore, split-geometry photoconductive detectors inherently have larger current path lengths and resistances than do those of nonsplit geometry; as a result, detector responses are greater and less power is dissipated.

The arrays operate with detectivity of about 3 to 4 × $10^{10}$ cm $Hz^{1/2}$/W cutoff wavelength as long as 18 μm. They satisfy all of the special requirements described above. The original application to which the special requirements pertain is to spacecraft instrumentation aboard the CIRS/Cassini spacecraft. There is need for arrays of similar design in other spacecraft; for example, detectors and arrays with similar design are being developed for the Geostationary Operational Environmental Satellite (see the following article). There is also a potential market in terrestrial, scientific, commercial, and military remote-sensing applications.

*This work was done by Bob Martineau, Andre Burgess, Sridhar Manthripragada, Frank Peters, Brent Mott, and Peter Shu of* **Goddard Space Flight Center**; *Kelley Hu and Jack Shi of HSTX; and Sachidananda Babu of Ball Aerospace. For further information, access the Technical Support Package (TSP) free* ***on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
*GSC-13812*

# High-Performance HgCdTe Detectors for Remote Sensing: Part 2

## Sweepout is reduced to improve performance.

*Goddard Space Flight Center, Greenbelt, Maryland*

The split-geometry design for arrays of photoconductive HgCdTe infrared photodetectors described in the preceding article can also be used to mitigate the deleterious effect of a phenomenon called "sweepout," which degrades performance. Sweepout occurs in conventional small HgCdTe photodetectors operated at high bias voltages; it causes undesired recombination of minority charge carriers at metal/semiconductor interfaces.

The split-geometry design improves performance by delaying the onset of sweepout to higher bias levels. It increases current-path lengths and thereby increases the electrical resistances of detectors. The split-geometry design is being used in the development of improved long-wave-sounder (LWS) detectors for the Geostationary Operational Environmental Satellite (GOES), and is expected to be used in the development of GOES imaging devices.

When detectors of split-geometry design are operated under optimal bias conditions, they exhibit responsivities and detectivities higher, and power dissipations and 1/f-noise knees lower, than those of conventional LWS photodetectors. By combining the split-geometry design with operation at relatively low bias, one can minimize the deleterious effect of sweepout. HgCdTe devices designed and operated following this approach have exhibited detectivities as high as 6 × $10^{10}$ cm $Hz^{1/2}$/W at a temperature of 80 K and a cutoff wavelength of 17.2 μm.

*This work was done by Bob Martineau, Andre Burgess, Sridhar Manthripragada, Frank Peters, Brent Mott, and Peter Shu of* **Goddard Space Flight Center** *and Kelley Hu and Jack Shi of HSTX. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
*GSC-13810*

# Improvements in Fabrication of HgCdTe Photodetectors

## Two modifications address issues of spectral response and cost of fabrication.

*Goddard Space Flight Center, Greenbelt, Maryland*

Two improvements have been made to solve two problems that arise in conjunction with a fabrication process in which an HgCdTe photodetector is mounted on an alumina substrate with epoxy. Although most of the HgCdTe-photodetector industry has abandoned this process in favor of epitaxial deposition, epoxy mounting is still used in some special applications.

The first problem is to reduce large variations in detector response as a function of wavelength; that is, to obtain more nearly even spectral response. The sharp variations in the spectral response are associated with resonances caused by interference between reflections from the alumina substrate and the front surface of the detector. The first improvement is to load the epoxy with 0.05-μm alumina grit; this solves the spectral-response problem by suppressing reflections from the substrate.

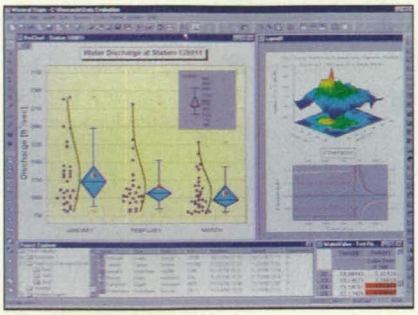
The second problem arises as follows: During the mounting procedure, the HgCdTe/epoxy/alumina structure is compressed, causing some of the epoxy to flow out and form a ridge around the perimeter of the HgCdTe wafer. The epoxy ridge prevents the use of contact photolithography in subsequent fabrication steps, making it necessary to resort to more expensive and difficult noncontact optical photolithography. The problem is to prevent the formation of the epoxy ridge so that contact photolithography can still be used.

Accordingly, the second improvement is to change the mounting procedure to prevent the formation of the epoxy ridge. In the improved mounting procedure, weight is applied to the HgCdTe/epoxy/alumina structure while the structure is heated. Any excess epoxy squeezed out is removed by use of solvent spray. The epoxy is then cured.

*This work was done by Bob Martineau, Andre Burgess, Sridhar Manthripragada, Frank Peters, Brent Mott, and Peter Shu of* **Goddard Space Flight Center**; *Kelley Hu and Jack Shi of HSTX; and Sachidananda Babu of Ball Aerospace. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*
*GSC-13811*

# NEW PRODUCTS

## PRODUCT OF THE MONTH



### Data Analysis and Graphics Software

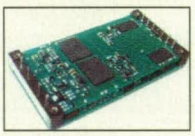
Microcal Software Inc., Northampton, MA, announces the release of Origin® 6.0, a Windows®-based data analysis and technical graphics software package. Features include a toolbar to mask out data points for investigating data in segments, an interface for customizing toolbars, a Plot Details dialog box for customization of every graphical element, and Project Explorer to warehouse experimental analysis. Origin 6.0 offers expanded graphic export filters, including PSD, EPS, PDF, DXF, and AI, among others. Formats for graphing support vector graphs, pie charts, and box charts. Origin now supports the use of color for value representation in 2D and 3D plots. Origin 6.0 is available for $595 for a single user. Current US Origin users can upgrade from version 5.0 for $199, or from an earlier version for $299.

**For More Information Circle No. 740**

### Pulse Discharge Capacitors

Maxwell Energy Products, San Diego, CA, offers the PD series high-voltage pulse-discharge capacitors, designed for high-repetition-rate applications up to 50,000 V. The series provides low-loss dielectric, rated from 5-50 kV, and high power efficiency, Maxwell says. The PDs are designed for maximum discharge up to 50 kA, and RMS current capabilities are available at 25, 35, 40, 45, and 60 A. Inductance is less than 20 nH. The company says pulse discharge life is $>1 \times 10^9$ charge-discharge cycles.

**For More Information Circle No. 741**



### Full-Brick DC-to-DC Converters

International Power Devices, Boston, MA, introduces the FES family of 200-W and 300-W DC-to-DC converters. The full-brick converters, measuring 4.6 × 2.4 × 0.5 in., are capable of providing up to 300 W of output power at up to 60 A of current. IPD says its high-efficiency power train enables the 200-W FES to deliver up to 89 percent efficiency at 5 V and up to 87 percent efficiency at 3.3 V. The company says the FES series uses advanced planar magnetics, synchronous rectification, and IPD's patented open-frame packaging to deliver exceptional thermal performance and high reliability.

**For More Information Circle No. 742**



### Moisture Barrier Bags

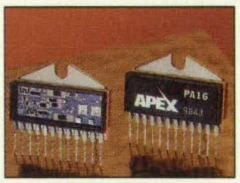
3M Electronic Handling and Protection Division, Austin, TX, says its 3300 moisture protection bag offers long-term protection from moisture, excellent high-frequency protection, and static shielding to protect the most sensitive electronic components or parts. Constructed of a durable multilayer 3.6-mil film that provides puncture and tear resistance, the bag meets the requirements of EIA-583 Class I and contains no amines, amides, or N-octanoic acid. The multilayer design eliminates problems associated with "pinholes" found in many foil-based barrier bags, according to 3M.

**For More Information Circle No. 744**


### 18-Bit Integrating A-to-D Converters

Advanced Linear Devices Inc., Sunnyvale, CA, introduces a family of monolithic CMOS analog-to-digital converters having resolutions of 16, 17, and 18 bits (plus sign bit and overrange bit). Designated the ALD500 series, the front-end analog processors have typical linearity errors of 0.001 percent full scale, 10-mW total power dissipation, 2-pA input current at OV, ±3.5-V input signal range, and a 1-µs fast zero-crossing comparator. Conversion speed can be regulated by an external microprocessor under software control or by utilizing fixed-logic digital inputs.

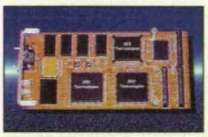
**For More Information Circle No. 745**




### Power Op Amp

Apex Microtechnology Corp., Tucson, AZ, says it designed its PA 16 5-A 38-V power op amp inside a Power SIP (single-in-line) package design measuring 1.2 × 0.87 in. to save on circuit-board space vis-a-vis its TO-3 counterpart. The PA 16 is housed in the 12-pin version of the Apex Power SIP, the flat-back design and isolated case of which allow for direct heat sinking. Internal power dissipation is 62.5 W. Apex says that with an efficiency of 1.2 V at 2 A, and 350 kHz of power bandwidth, the PA 16 is well-suited to driving inductive and capacitive loads. An evaluation kit, the EK 14, is available for prototyping.

**For More Information Circle No. 746**



### Interfaces on PCI Mezzanine Cards

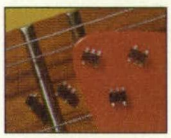
Designed for embedded avionics applications, the ABI-PMC and ASF-PMC products from SBS Avionics Technologies, Albuquerque, NM, provide flexible, full-function, or single-function MIL-STD-1553 interfaces in a PCI mezzanine card. The company says their primary advantage is the ability to operate with the 16PP362 F-16 Advanced Weapons Multiplex Data Bus. The ABI-PMC provides concurrent and independent operation of a bus controller, 31 remote terminals, and sequential and/or mapped bus monitoring. The ASF-PMC provides similar capability in a single-function mode: bus controller or a single remote terminal or monitoring.

**For More Information Circle No. 747**

### Single-Layer Border Capacitors

AVX Corp., Myrtle Beach, SC, introduces a line of single-layer border capacitors with recessed metallization on one or both sides to reduce the incidence of shorting when using conductive epoxy. Called the SLC series, the chips are available in all of AVX's standard dielectric materials, including its exclusive Maxi material. All border-style capacitors have gold metallized terminations of 100 microinches over a barrier layer. The SLC series features capacitance values from 0.10 to 5,600 pF with tolerance to ±0.1 pF. Operating temperature range of all materials is -55 °C to +125 °C.

**For More Information Circle No. 748**



### Low-Dropout Voltage Regulators

Rohm Corp., Antioch, TN, adds to its line of low-dropout voltage regulators (LDOs) with the BAxxxLBSG series of low current, compact (SOT-23) LDOs suitable for portable equipment. The regulators are offered at output voltages from 2.8 to 5 V, in increments of 100 mV, with a tolerance of 2.5 percent. The devices are rated for a minimum current of 150 mA, with a typical output current of 280 mA. Package power dissipation is 170 mW maximum. In addition to input, common, and output pins, the series have a logic-controlled standby pin that turns off the output to that part of the circuit and reduces the quiescent current to less than 10 µA (typically 0.1 µA).

**For More Information Circle No. 749**

### Contact Resistance Meter

The 3560 AC milli ohm HiTester from Hioki USA Corp., Cranbury, NJ, is a contact resistance meter capable of the measurement requirements ranging from relay contacts to internal resistance and voltage of batteries. In the FAST mode, it provides 60 measurements per second, yielding a response time of approximately 84 ms (at 60 Hz), which Hioki says is the fastest of any instrument in its class. Other features include 1 micro-ohm resolution, and a new resistance/voltage mode that combines the functions of a milliohm meter and digital multimeter in one unit, allowing it to be used on battery testing lines to simultaneously measure circuit voltage and internal resistance of batteries.

**For More Information Circle No. 750**

# Liquid-Circulation System Keeps Aircrew Members Cool

## Flight-test pilots have expressed approval.

*Dryden Flight Research Center, Edwards, California*

Each member of the aircrew of an advanced fighter airplane wears a complex, multilayered ensemble that imposes a significant thermal burden by inhibiting normal transport of heat from the body. The thermal burden may be aggravated by the use of nuclear, biological, and chemical (NBC) protective clothing, insolation through the canopy, psychological mission stress, and, in the future, positive-pressure breathing equipment used in COMBAT EDGE (Combined Advanced Technology Enhanced Design "G" Ensemble) equipped aircraft. The inability of the body to rid itself of excess heat can, at the very least, cause discomfort, but can also degrade mission effectiveness and pose a serious threat to safety and health. The aircrew personnel environmental control system (APECS) was designed to satisfy the need to remove excess heat from the body under these conditions. The APECS can also be used to keep pilots relatively cool when waiting for long times on the ground in hot weather, as well as in flight.

The APECS is a liquid-circulation cooling system (see Figure 1) that comprises two basic subassemblies — (1) the crew side, which is donned by each aircrew member, and (2) the aircraft side, which is permanently installed in each aircraft. The crew side (see Figure 2) consists of a cooling garment worn under the flight suit, tubing, and a quick-disconnect assembly for emergency egress. The aircraft side contains a network of plumbing, two heat exchangers, and a pump to chill and circulate the cooling fluid. The fluid consists of 70 percent distilled water and 30 percent denatured alcohol, plus a trace amount (150 parts per million) of sodium nitrate to inhibit corrosion in the pump. In future versions of this system, the pump will contain polytetrafluoroethylene gears, eliminating the need for sodium nitrate.

Figure 1 schematically depicts the APECS. The two heat exchangers in the aircraft side of the APECS are tied into the environmental control system (ECS) of the aircraft for cooling of the fluid. The fluid passes to thermal contact with the crewmember through tough nylon tubes worn close to the skin and, via thermal conduction, removes excess heat from the crewmember. The cycle is completed by pumping the heated fluid back to the heat exchangers for cooling. The temperature of the fluid pumped to the crewmember can be controlled manually by adjusting

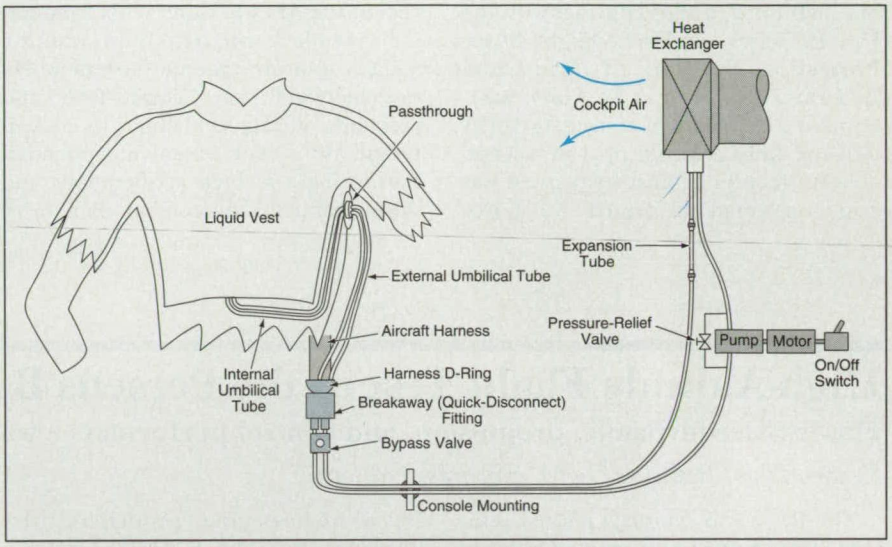
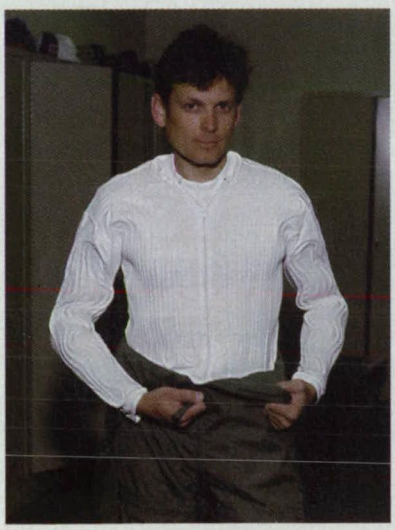



Figure 1. **A Heat-Transfer Liquid Is Circulated** between heat exchangers and a liquid vest to cool the wearer.



Pilot Wearing APECS Garment Under Flight Suit


Quick-Disconnect Assembly

Figure 2. The **APECS Garment and Quick-Disconnect Assembly** are parts of the crew side of the APECS. The garment is worn under the flight suit. The quick-disconnect assembly is needed so that the APECS will not impede emergency egress.

the cockpit air temperature via the ECS. During the winter, the heat-exchange process can be reversed by increasing the cockpit air temperature via the ECS, allowing warm fluid to pass through the APECS. The system includes a bypass that enables the crewmember to elect not to use the APECS while keeping cooled or heated fluid circulating in a standby mode.

The APECS hardware was originally designed and tested in the laboratory by Foster-Miller, Inc., of Waltham, Massachusetts, under contract with the United States Air Force Flight Stress Protection Division of Armstrong Laboratories at Brooks Air Force Base. Human physiological testing to verify that the APECS would provide acceptable protection against heat stress was also conducted at Brooks Air Force Base. Having been proven in the laboratory, the APECS was then provided to NASA Dryden Flight Research Center for installation in an aircraft for field testing.

NASA elected to use the F-16XL aircraft as the test bed, inasmuch as this aircraft is flown by NASA as well as visiting Air Force Flight Test Center pilots. This gives the APECS exposure to a wide cross section of crewmembers with different physiological characteristics. To date, flight tests have proven the success of the APECS. Comments from aircrew members who have flown with the APECS indicate that the system works extremely well, is very comfortable, and responds quickly to changes in cockpit temperature. The system has operated during flight at high accelerations and during simulated air combat maneuvers, with no loss of cooling and without noticeable effect on the mobility of the pilot under acceleration load.

Although the APECS is now installed in the F-16XL only, work is in progress to put the APECS in a two-seat F-15 aircraft as well as in a single-seat F-18 aircraft at NASA Dryden Flight Research Center. Plans for the future also provide for the incorporation of a preflight cooler to help control body temperature on the ground and in the cockpit prior to connection of the crew side of the APECS with the aircraft side.

*This work was done by Nick Kiriokos and Mark Collard of* **Dryden Flight Research Center** *and Dan Fischbach of Foster-Miller, Inc. No further documentation is available.*
*DRC-98-86*

# High-Altitude Flight Test of the Perseus B Airplane

**Flawless aerodynamic, propulsion, and control performance was observed.**

*Dryden Flight Research Center, Edwards, California*

The Perseus B remotely piloted vehicle (RPV) has achieved a record altitude for a single-engine, propeller-driven airplane of 60,260 ft (18,367 m) on June 27, 1998. The Perseus B is one of the test-bed aircraft developed under NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program for use in conducting high-altitude, long-duration missions carrying atmospheric sampling and sensing payloads for the scientific community within NASA and other agencies.

The Perseus B (see figure) is a slender, high-aspect-ratio airplane powered by a fuel-injected, four-cylinder ROTAX 912 engine aspirated by a three-stage, four-turbine turbocharger system with intercooling. Heat exchangers for the engine and intercooler coolant loops are a prominent feature on the center fuselage and under-wing positions. The engine is buried within the aft fuselage section, with a carbon-composite drive shaft extending rearward to drive a high-altitude, low-Reynolds-number-optimized two-blade propeller.

The airplane was demonstrated to fly at indicated airspeeds from 45 to 70 knots (23 to 36 m/s) and to climb at a healthy rate of 200 ft/min (1 m/s) at an altitude of 60,000 ft (≈ 18 km). The ascent to this altitude takes about 170 minutes, corresponding to an average climb rate of about 350 ft/min (≈1.8 m/s).

Because of the developmental aspects of the flight, the maximum altitude was maintained only momentarily before descent was initiated. Temperatures


The **Perseus B** is a remotely piloted airplane designed to carry scientific instruments for research at high altitudes.

encountered at altitude were as low as –70 °C, and proved too harsh for some components, including a Mode 3C Federal Aviation Administration radar transponder, which ceased operating at an altitude of approximately 53,000 ft (≈16 km), and began operating again at approximately 38,000 ft (≈12 km) after it had warmed sufficiently. Global Positioning System (GPS) data became intermittent above 57,000 ft (≈17 km), but because the GPS data stream returned upon descent through the same altitude, the intermittency is thought to be due to software lockout rather than thermal effects. Both of these anomalies are easily correctable by (1) adoption of better thermal management of the environment of the transponder (e.g., installation of a heating blanket), and (2) obtaining the correct GPS software for use at high altitude. The aerodynamic performance of the airplane and the performances of its propulsion and control systems were flawless throughout the flight.

Prior to the 60,000-ft flight, three other flights to altitudes of 15,000 ft (≈4.6 km), 27,000 ft (≈8.2 km), and 45,000 ft (≈14 km), respectively, were made as envelope-expansion missions. Data obtained from the total of four flights are being analyzed. The results of this analysis will be used to modify the aircraft to fly longer at 60,000 ft, as well as to increase the reliability and robustness of aircraft systems, including the data link and flight-control logic. These modifications will prepare the Perseus B aircraft for another flight-test phase to demonstrate the duration at altitude and mission-readiness of the aircraft and test team. Following this phase, it is expected that the aircraft will be ready for work in flying instruments and sensors for scientific missions.

The aircraft will be capable of carrying a nominal payload mass of 176 lb (80 kg) for 8 hours on station at 60,000 ft. It can carry as much as 265 lb (120 kg) on a mission of longer duration at lower altitude. Up to 1 kW of electrical power at a potential of 28 V can be provided to the payload. The flight-test techniques developed and experience gained from this first Perseus B deployment will be utilized in improving the safety and efficiency of future flight-test programs for ERAST and other unpiloted-aircraft projects at Dryden Flight Research Center. Technical information is collected and used by all of the ERAST Alliance members to further the development and mission-readiness of high-altitude, long-duration uninhabited scientific aircraft.

*This work was done by Aurora Flight Sciences Corporation and managed by Gary B. Cosentino for* **Dryden Flight Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category. DRC-98-89*

# Programmable Multizone Directional-Solidification Furnaces

**These furnaces would afford improved capabilities for shaping and translation of thermal gradients.**

*Marshall Space Flight Center, Alabama*

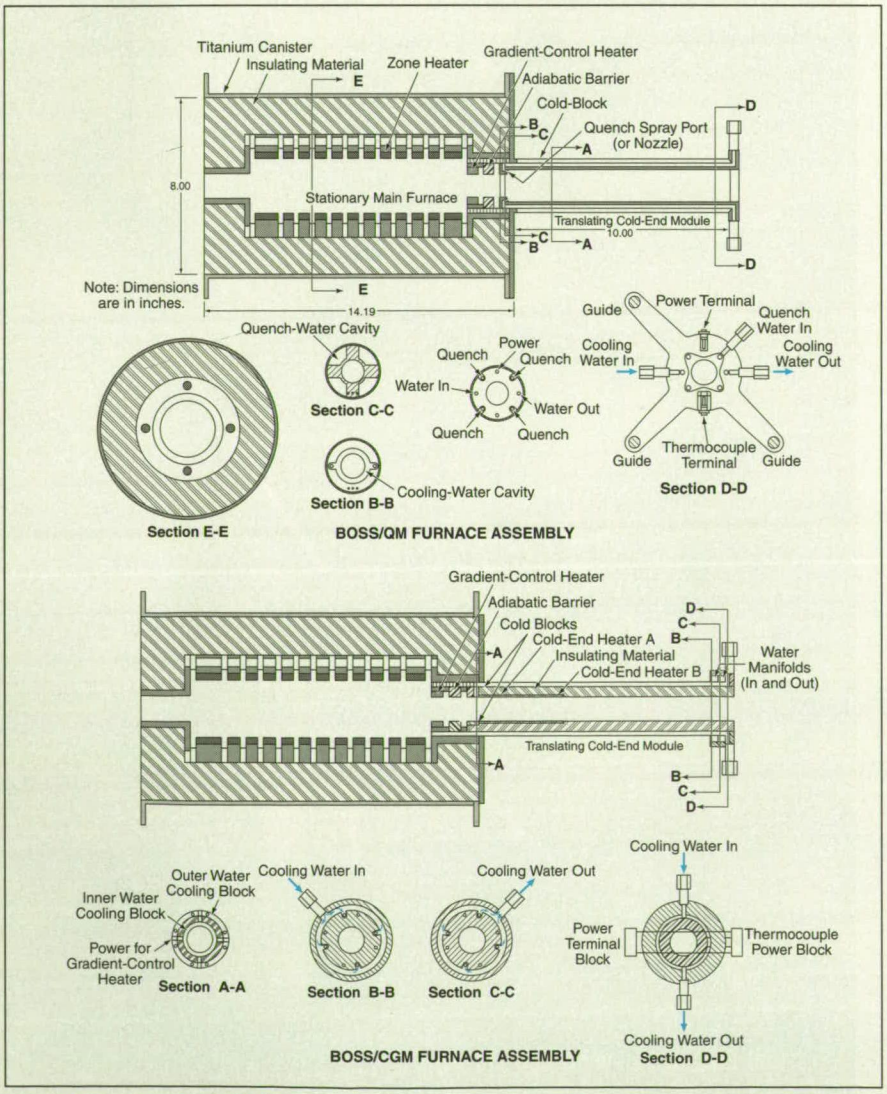
Programmable multizone furnaces with enhanced designs have been proposed for use in processing materials by directional solidification or, optionally, by related techniques of float-zone or isothermal solidification. Like some other directional-solidification furnaces reported previously in *NASA Tech Briefs* and elsewhere, these furnaces would incorporate multiple, individually controllable electric heaters stacked at a succession of axial locations in a stationary cylindrical main canister for generating, shaping, and translating specified axial temperature profiles (specified temperatures and/or temperature gradients) under electrical control. These furnaces would also incorporate cold-end modules that could be translated axially and telescoped into the main canisters to provide additional versatility for control of cold-end temperature profiles.

Because it would afford options for a combination of mechanical (translational) and electrical control of temperature profiles, a furnace of this type would be called a "bi-operational solidification system" (BOSS) to distinguish it from older multizone furnaces that feature electrical or translational (but not both) modes of temperature-profile control. The BOSS concept offers opportunities for achieving (1) compact furnace design, (2) increased versatility for programming a variety of stationary and moving temperature profiles, and (3) high thermal efficiencies through reduced (relative to other directional-solidification furnaces) heat losses, with total power-consumption levels comparable to those of translation (only)-type directional-solidification furnaces.

A typical BOSS (see figure) would include 12 zone heaters separated by spacers that would reduce heat conduction between zones and thereby also enhance thermal control of each zone. The axial lengths of the end heaters would be made greater than those of the other heaters to provide additional heat capacity to overcome heat losses from the ends. Each heater would comprise an electrically resistive wire wound in a groove on the radially outermost edge of a washerlike disk of thermally insulating material. (Consequently, each heater would act as an insulator when not powered.) Thermocouples for measuring temperatures in the heater zones would be included. Power and thermocouple leads could be routed axially or radially through a layer of insulating material that would surround the heaters.

The cold-end module could be of either of two types: (1) a quench module (QM) or (2) a crystal-growth module (CGM). A QM would include a water-cooled cold block (or quench block), a quench-spray port or nozzle at the entrance to the cold block, and a gradient-control heater separated from the cold block by an adiabatic barrier. In conjunction with the zone heaters in the stationary main canister, a QM would provide a controllable, translatable temperature gradient.

A CGM would also include a gradient-control heater and an adiabatic barrier,




Two **BOSS Furnace Assemblies** are shown in simplified form to illustrate the arrangement of major components. For the sake of clarity, outer containers and drive mechanisms for translating the cold-end modules are omitted from these drawings.

but would differ from a QM in that the quench capability would be replaced by a cold-end temperature-control capability. Instead of a single cold block, there would be two cold blocks, which could be actively cooled by water or operate in a passive (uncooled) mode. Two cold-end heaters mounted on a common mandrel would provide a capability for finer control of the cold-end temperature profile.

*This work was done by Jack E. Robertson of AI Signal Research, Inc., for* **Marshall Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*
*MFS-26524*

# Scanning Surface-Plasmon Filters for Miniature Spectrometers

## Sizes and masses of spectrometers could be reduced greatly.

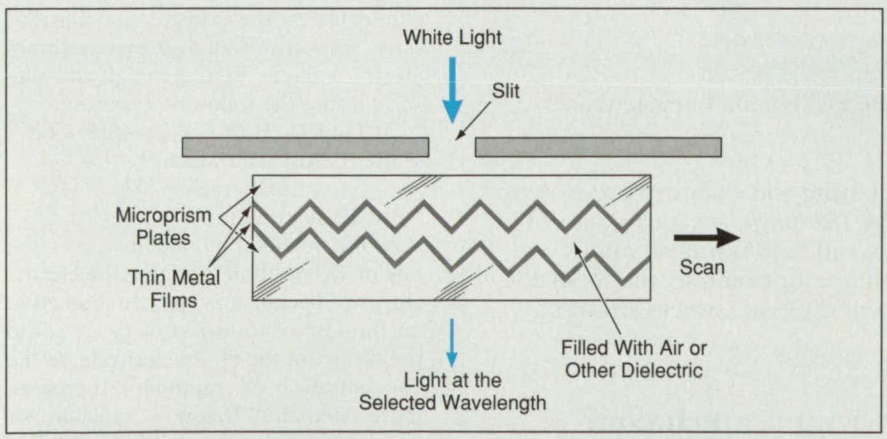
*NASA's Jet Propulsion Laboratory, Pasadena, California*

Scanning filters based on surface plasmons would be used as the adjustable wavelength-selective (band-pass) devices in a class of proposed miniature spectrometers. These filters would occupy much less space and weigh much less than do the diffraction gratings and other wavelength-selective optics of conventional spectrometers; as a result, the proposed spectrometers would be correspondingly smaller and less massive.

In a recently developed tunable band-pass filter [*NASA Tech Briefs*, Volume 22, No. 8 (August 1998), page 18a] based on surface plasmons, the pass wavelength band is adjusted by changing the airgap between two prisms. The filters in the proposed spectrometers would implement an alternative approach to tuning. A filter of this type would include two glass plates separated by a narrow gap filled with air or another dielectric with a low index of refraction. The facing surfaces of the plates would be grooved to form microprisms and coated with thin metal films. In a typical example, the dielectric would be air and the microprisms would be made of BK-7 (or equivalent) glass, formed for an angle of incidence of 41.5 °C, and coated with silver to a thickness of 40 nm.

The microprism plates would be tilted slightly to make the gap thickness vary from one edge to the other. The assembly of plates would be mounted on a scanning mechanism below a spectrometer slit, so that by use of the mechanism, the thickness of the gap illuminated through the slit could be varied. Inasmuch as the wavelength of peak transmission would depend on the thickness of the gap, scanning by use of the mechanism would thus result in variation of the pass wavelength band. In the example cited above, scanning from a gap 300 nm thick to a gap 5,000 nm thick would shift the wavelength of peak transmission from 400 to 1,600 nm.

*This work was done by Yu Wang and Bedabrata Pain of Caltech for NASA's Jet Propulsion Laboratory. For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences categaory.*
*NPO-20179*




This **Band-Pass Filter Based on Surface Plasmons** would feature a tapered gap between microprism plates. A scanning mechanism would be used to translate the microprism plates sideways to select the desired gap thickness and thus the desired wavelength of peak transmission.

# Sensor for Monitoring Concentration of Methanol in Water

## Speed of response and dynamic range exceed those of other methanol sensors.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A robust sensor based on the electrochemical oxidation of methanol has been developed for use in measuring the concentration of methanol dissolved in water. The sensor is expected to be particularly useful in continuous monitoring and control of the concentration of an aqueous solution of methanol metered into a liquid-feed, direct-oxidation methanol fuel cell.

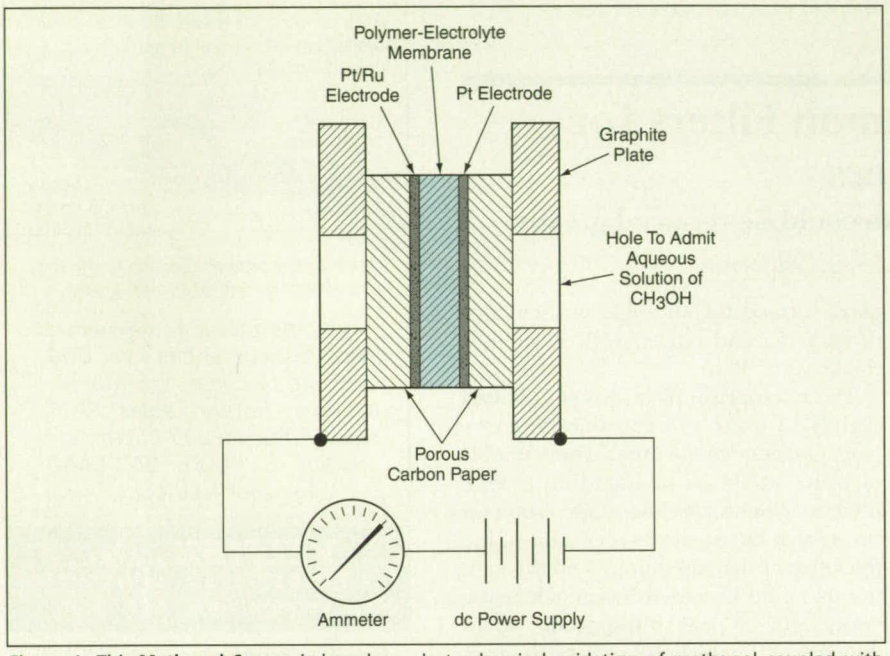



Figure 1. This **Methanol Sensor** is based on electrochemical oxidation of methanol coupled with electrochemical reduction of water.

Other methanol sensors respond to changes in concentration too slowly to be useful for monitoring and control. Moreover, methanol sensors based on spectroscopy are relatively insensitive at high concentrations. The present sensor responds rapidly enough for monitoring and control. It also offers wide dynamic range; it can measure concentrations from 0.01 M to 5 M. Furthermore, it functions over the entire temperature range of liquid water at normal atmospheric pressure; that is, from 0 to 100 °C.

The sensor (see Figure 1) resembles a small liquid-feed, direct-oxidation fuel cell in some respects, but is operated in a different manner. It includes a polymer-electrolyte membrane coated on one side with a catalytic electrode composed of Pt/Ru-alloy powder and coated on the other side with a catalytic electrode composed of Pt black. Some details of the preparation of the Pt/Ru powder, the polymer-electrolyte membrane, and coating the membrane with the Pt/Ru powder were described in "Making Catalysts and Electrodes for Liquid-Feed Fuel Cells" (NPO-19893) *NASA Tech Briefs*, Vol. 20, No. 10 (October 1996), page 60. The coated membrane is pressed between sheets of the porous carbon paper. The resulting sandwich is mounted between graphite plates that act as both current collectors and structural supports. Circular openings in the graphite plates expose the sandwich to the aqueous solution of methanol.

When the Pt/Ru and Pt electrodes are connected to the positive and negative sides, respectively, of a dc power supply, electric current flows through the sensor, causing the following reactions:

$$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$$

at the Pt/Ru electrode and

$$6H^+ + 6e^- \rightarrow 3H_2$$

at the Pt electrode.

As the applied potential increases, the rate of this reaction (and thus the electric current) becomes subject to limitation on the rate of transport of methanol to the surface of the Pt/Ru electrode. As the concentration of methanol increases, more methanol becomes available for transport, making it possible to sustain a larger transport-limited current. Thus, for a given applied potential, the current

increases with the concentration of methanol (see Figure 2). This behavior is exploited in designing the methanol sensor; in the basic mode of operation, one applies a specified potential in the range in which current is strongly transport-limited (e.g. 0.63 V) and measures the current as an indication of the concentration of methanol.

The response of the sensor also depends on temperature. At each operating temperature of interest, the sensor is calibrated by applying the potential and measuring the current in the presence of aqueous solutions with known concentrations of methanol.

*This work was done by Sekharipuram Narayanan, William Chun, and Thomas Valdez of Caltech for* **NASA's Jet Propulsion Laboratory.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to*

*Technology Reporting Office*
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*Mail Stop 122-116*
*4800 Oak Grove Drive*
*Pasadena, CA 91109*
*(818) 354-2240*

*Refer to NPO-20125, volume and number of this* NASA Tech Briefs *issue, and the page number.*

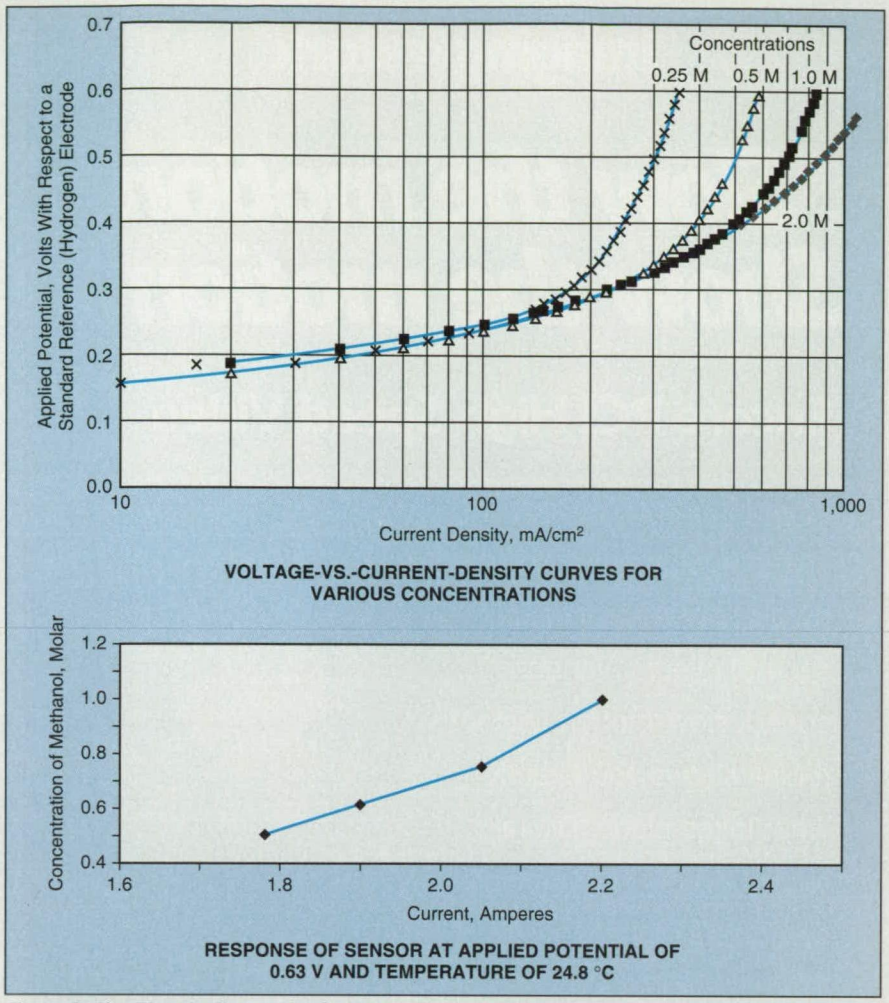



Figure 2. The **Electric Current in the Sensor** increases with the applied potential and with the concentration of methanol in water. The current also depends on temperature. For a specified temperature and applied potential, the current thus serves an indication of the concentration of methanol.

# Foam Heat Exchangers

## Heat exchangers and pumps can be made smaller, lighter, and less expensive.

*Lewis Research Center, Cleveland, Ohio*

Experiments have demonstrated the feasibility of heat exchangers with flow channels containing open-cell metallic foams. Nonmetallic foams could also be used. One proposed design calls for an open-cell foam in the annular region between an inner and an outer tube, with a heat-transfer fluid flowing along the annular region while either the outer or the inner tube is heated by flowing hot gas. Heat would be transferred from the heated tube wall to the fluid with an efficiency greater than that of a simple tube heat exchanger. The increase in heat-transfer efficiency would result from the large surface area of the foam in contact with the cooling fluid and from turbulence induced by the ligaments of the foam in the flow path. Thermal conduction between the wall and the foam would also make a small contribution.

Greater heat-transfer efficiency should make it possible to design smaller, lighter heat exchangers for some applications. Another advantage of foam heat exchangers is that all flow paths through foam are interconnected, so that if a flow becomes obstructed by debris lodged in foam at one place in a channel, the flow can continue elsewhere in the channel; in other words, complete blockage of a channel is unlikely. This is in contrast to the situation in a heat exchanger containing narrow brazed tubes and/or narrow, precisely machined channels, which can become blocked more readily. Moreover, in comparison with machined-channel and brazed-tube heat exchangers, foam heat exchangers can be fabricated more easily and at lower cost.

Remarkably, a properly designed foam heat exchanger exhibits less back pressure than does a machined-channel or brazed-tube heat exchanger of equal heat-transfer capacity. Thus, a smaller pump can be used to circulate the heat-transfer fluid.

*This work was done by Arthur J. Fortini and Robert H. Tuffias of Ultramet for* **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Station, Mail Stop 7–3, 21000 Brookpark Road, Cleveland, Ohio 44135.*
*Refer to LEW-16579.*

# Books & Reports

## Model-Based Monitoring for Spacecraft Thruster Leakage

A report describes a method of detecting leakage in one of the 16 thrusters of the Cassini spacecraft. The detection method, implemented as part of the spacecraft flight software, is based on the fact that the three-axis rotational motion of a spacecraft is governed by the Euler's equation. The left-hand side of the Euler's equation contains both the inertia and gyroscopic torques, which are estimated by the attitude estimator of the attitude control software. The right-hand side of the Euler's equation contains reaction torques from both the thrusters and the reaction wheels which are also estimated.

*This work was done by Allan Y. Lee of* **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "A Model-based Thruster Leakage Monitor for the Cassini Spacecraft" access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Mechanics category.*
*NPO-20441*

## Details of Apparatus for Advanced Ultrasonic C-Scan Imaging

A report comprising the main contents of U. S. Patent 5,750,895 presents detailed information on the subject of "Apparatus for Advanced Ultrasonic C-Scan Imaging (GSC-13524), *NASA Tech Briefs,* Vol. 21, No. 4 (April 1997), page 34. The apparatus is a computer-controlled ultrasonic C-scan instrumentation system that includes an ultrasonic transducer, an electronic pulser/receiver, a dual timing gate, a peak detector, and a timer.

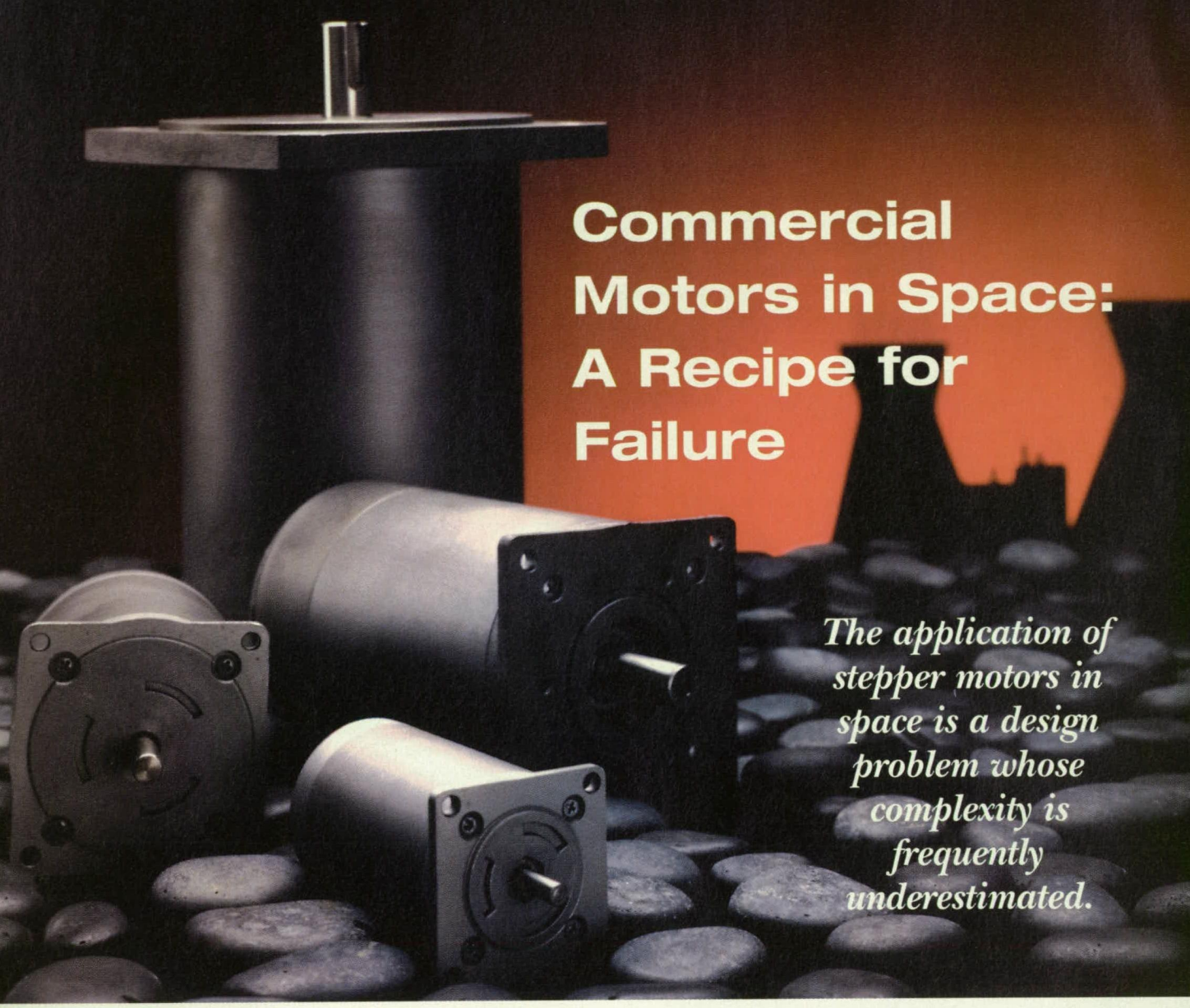
*This work was done by Engmin James Chern and David W. Butler of* **Goddard Space Flight Center.** *To obtain a copy of the report, "Method and Apparatus for Dual Amplitude Time-of-Flight Ultrasonic Imaging," access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-13524-2.*

# Motion CONTROL Tech Briefs



*Cover art courtesy of Empire Magnetics Inc. See "Commercial Motors in Space."*



# Commercial Motors in Space: A Recipe for Failure

*The application of stepper motors in space is a design problem whose complexity is frequently underestimated.*

*Gamma radiation attacks non-metallic materials in a motor, resulting in the deterioration of lubricants, varnish, lamination bonding, and cable insulation over time.*

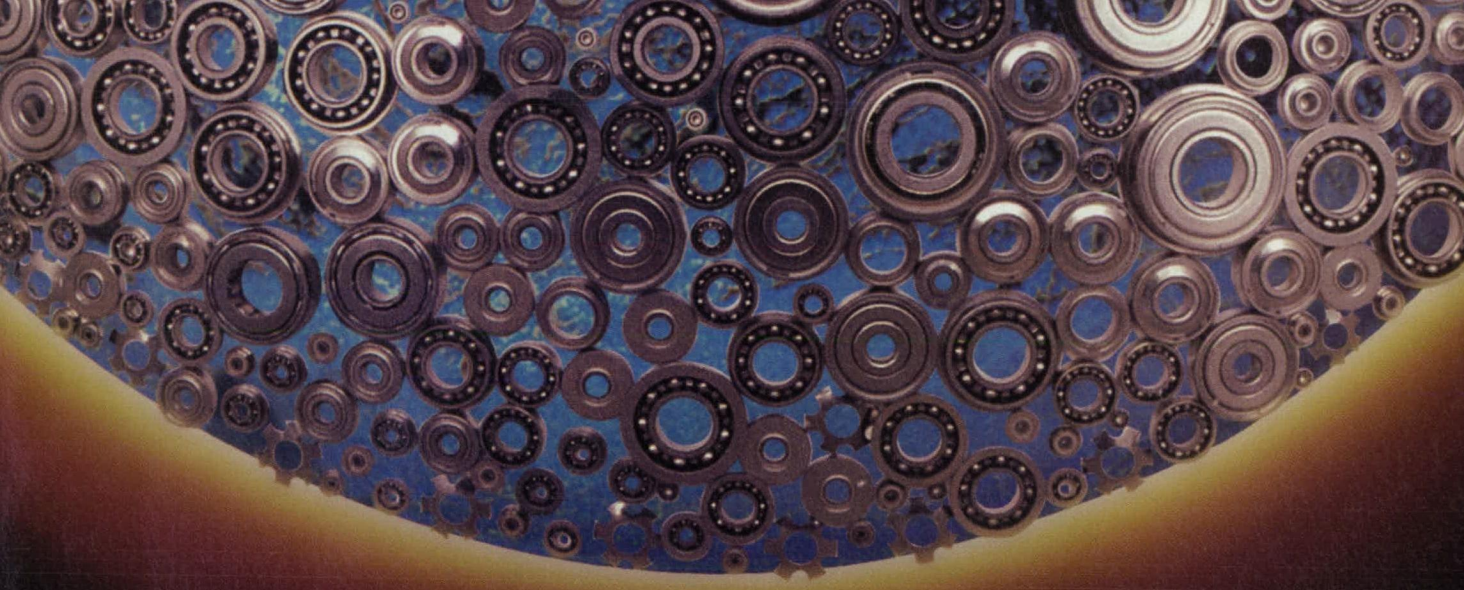
The environmental challenges of space-related stepper motor applications are immense. While most of the research in this field has focused on bearings and lubrication, there are a number of other issues to be considered. These include vacuum ($10^{-8}$ to $10^{-12}$ torr), deep space cryogenic (20 Kelvin), thermal shock (sun at +200 °C to shade at -200 °C in one to two seconds), launch vibration, ionized particles, and radiation. In addition, there are a limited power budget, severe weight and size restrictions, and reliability and life requirements.

Many engineers approach these problems by assuming that standard commercially made motors are the correct basis from which to construct a motor for space applications. Unfortunately this assumption is incorrect. Designers of commercial motors focus on reducing the cost of high-volume production of standardized products. While there is certainly a drive towards 100% quality, the cost penalty for motor failure in the industrial/commercial world is relatively low and the reward for cutting costs is high. Therefore the commercial design goal is a prescription for disaster in space-flight applications.

## Electrical Failure

Electrical failure in a motor is simple. Either the wires short out, or they break and the circuits open. To improve the reliability of the motor, insulation materials can be upgraded, and special attention must be paid to the lead wire connections between the motor and the electronics. A careful thermal analysis to assure sufficient cooling capacity of the system is also important for electrical reliability.

Empire Magnetics has fully reviewed redundant motors and redundant windings on each space program we have consulted on, and each time the user has ruled this approach out due to the weight penalty inherent in mechanically redundant motors. We have concluded that the most pragmatic solution is



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having redundant electrical circuits in the same mechanical motor housing.

Redundant windings are required to support redundant electrical circuits. Simply winding the coils by taking two pieces of wire in hand (bifilar) offers redundancy against bad solder joints, broken lead wires, and failed electronics. But this does little to protect against overheating and insulation failures, and the probability of both wires being damaged in the same thermal event is great. Two separately wound coils inserted with a phase separator are less prone to fail, but a thermal meltdown is still likely to destroy both windings.

To compound matters, the slot areas of the motor were designed to have a single coil filling the entire slot. If one tries to install two coils into the slot, each can only contain half the normal wire amount. Since motor torque is a function of amps times the number of coil turns squared, it will take about four times as much current to achieve full torque in the motor when using a half coil. Since coil heating is a direct result of amps squared times the resistance of the coil, coil heating in a redundant winding is likely to be 4-16 times greater than a normal coil.

Oversizing the motor to make up for torque loss increases the weight nearly as much as making the motor fully redundant. To date, all space flight designs have compromised by using bifilar windings, redundant electronics, redundant lead wires, and slightly oversized motors, backed up by mechanical and thermal modeling and extensive testing.

In addition to electrical shortcomings for space applications, the typical standard commercial motor is manufactured from magnetic iron, which is stamped, coated, glued, stacked, and assembled into the basic motor structure. These first few construction steps lead to an entire series of problems for motors in space applications, namely outgassing and mechanical ones.

*Empire's space motors are designed and constructed to meet the environmental challenges of space-related applications, including vacuum ($10^{-8}$ to $10^{-12}$ torr), deep space cryogenic (20 Kelvin), thermal shock (sun at +200 °C to shade at -200 °C, in 1-2 seconds), launch vibration, ionized particles and radiation exposure.*

## Vacuum Outgassing

Outgassing is a major reason why commercial motors are an inappropriate choice for a space application. In a vacuum environment, the lubricants typically found in the bearings of standard motors will vaporize and the organic materials will evaporate—the phenomenon known as outgassing. Some materials like petroleum-based grease vaporize so quickly that they literally create clouds of vapor in a vacuum chamber. Other materials such as silicone lubricants vaporize more slowly, but result in serious application problems of their own. NASA has funded numerous studies on lubricants, and much of the data can be found in NASA publication 1124 (this data is too extensive to be covered here).

The insulation material and lamination cement or glue used in the stator of a commercial-grade motor are selected for rapid application and low cost, with no concern for vacuum outgassing. During the stamping operation, lubricants are added to reduce tool wear. If not carefully removed, these trace materials too will outgas into the vacuum, causing a variety of problems. The metal coating process traps these same die lubricants, making it more difficult to remove them, and the coating itself may or may not be vacuum-compatible.

The motor stator is manufactured by adding insulation materials around the laminated core, winding wire coils, adding the lead wires, and impregnating the windings with varnish (a metal housing may or may not be used to enclose the stator core assembly). Adding to the range of problems, the varnish used to impregnate the windings is a hard material intended to maintain coil positions. This varnish is susceptible to outgassing and hides the electrical connections from inspection.

## Mechanical Issues

In addition to material outgassing, there are a number of mechanical issues related to the design and manufacture of standard commercial motors which are important to the spacecraft designer. The stamping operations used to provide low-cost motor parts also introduce stress into the metals. The stresses will be relieved by the launch vibration and thermal cycling experienced in space, which cause the parts to change their mechanical shape. Motor failure is a likely result.

Broken shafts are typically due to weight and size restrictions placed upon the designer. Even a slight misalignment between the motor and a rigidly coupled load will bend the shaft as it is rotating. This bending fatigue is aggravated by snap-ring grooves or machined cuts, and brittleness at cold temperature. When gears are used to multiply motor torque, the potential for shaft breakage increases.

The shock, vibration, and thermal cycling common in space, coupled with improper material selections or treatments, can cause severe metal distortion. Warping can cause mechanical lockup of the motor. Thermal cycling and differential material expansions can also cause motor lockup.

The challenges imposed on motors by outer-space applications are immense, and making the false assumption that a commercial-grade motor is an appropriate starting point will only expand the problem. Just as a NASCAR Team wouldn't use the motor of a Ford Escort as the building block for their Indianapolis 500 run, space researchers shouldn't use a standard commercial-grade motor as the building block for space exploration. It may be a quality motor; it simply isn't right for the application at hand.

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common vacuum chamber/motor design problems, including outgassing, cooling, air leakage, and corona effects. Empire vacuum motors undergo a proprietary extraction process to remove lubricants, volatile polymers, and other extraneous materials used in the manufacturing process.

Take the example of the Wake Shield Satellite. The Wake Shield team was planning to position the satellite's solar panels using motors and gearboxes. Recognizing the technical challenges inherent in outer-space applications, the design team turned to Empire Magnetics. By selecting materials based on thermal characteristics and holding tighter mechanical tolerances, potential problems were avoided in three successful orbital missions. A fourth launch is planned, and to date, no motor or gearbox maintenance has been necessary.

Another case involved satellite stabilization. Most commercial motors feature bearing-holding plates constructed of porous cast aluminum which is machined. This aluminum holds air and other contaminants that can lead to outgassing problems. In addition, the aluminum has a different expansion coefficient from the steel or iron of the motor body. The differentials result in mechanical problems during thermal cycling.

Orbital Flight Systems needed assemblies for satellite inertial controls. Empire engineers constructed units of heavier material to improve mechanical stability and reliability. While the weight increase was contrary to the stated desires of the satellite designer, analysis demonstrated that a motor failure would lead to the failure of a multi-million-dollar satellite system while in orbit. Faced with this responsibility, the designer opted for reliability.

Empire Magnetics has provided an array of motors, gearboxes, brakes, and other components for the yet-to-be-launched Space Station. A number of servo motors are used to position the docking rings which move into position to match the craft—meaning the Shuttle pilot no longer needs to adjust the position of the ship to ± four inches. Once in location, another group of Empire motors and gearboxes latch and lock the mating rings together. In all, Empire has supplied more than 30 units for both ground support and flight assemblies on the space station.

## Brilliant Eyes

Many spacecraft designers are predisposed to selecting a motor sans housing. In their quest to reduce motor weight they select a mechanical design that is relatively unstable considering the reliability requirements of their application. They tend to compound the problem by selecting long, thin motors, which are less stable and reliable than shorter, thicker ones.

While working on the Brilliant Eyes program, Boeing, Corning OCA, and Space System Group avoided these issues by accepting Empire's recommendation of a design based on CYVX-U21 and CYVX-U31 motor construction. These platforms have already addressed material and process issues, they are of the most reliable configuration, they have been mechanically stabilized, and they have heavier housings. The Brilliant Eyes team has qualified the first set of motors in operation at 24 Kelvin and subjected to 25-g shock; qualifications were made without secondary rework or modification.

*For more information, contact the author of this article, Richard Halstead, president of Empire Magnetics, Inc. He was previously a test equipment engineer and programmer for IBM, and applications engineer and sales manager with Compumotor. He can be reached at (707) 584-2801, or via E-mail at rick@empiremagnetics.com.*

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**For More Information Circle No. 645**

# Machined Springs: a Very Good Solution

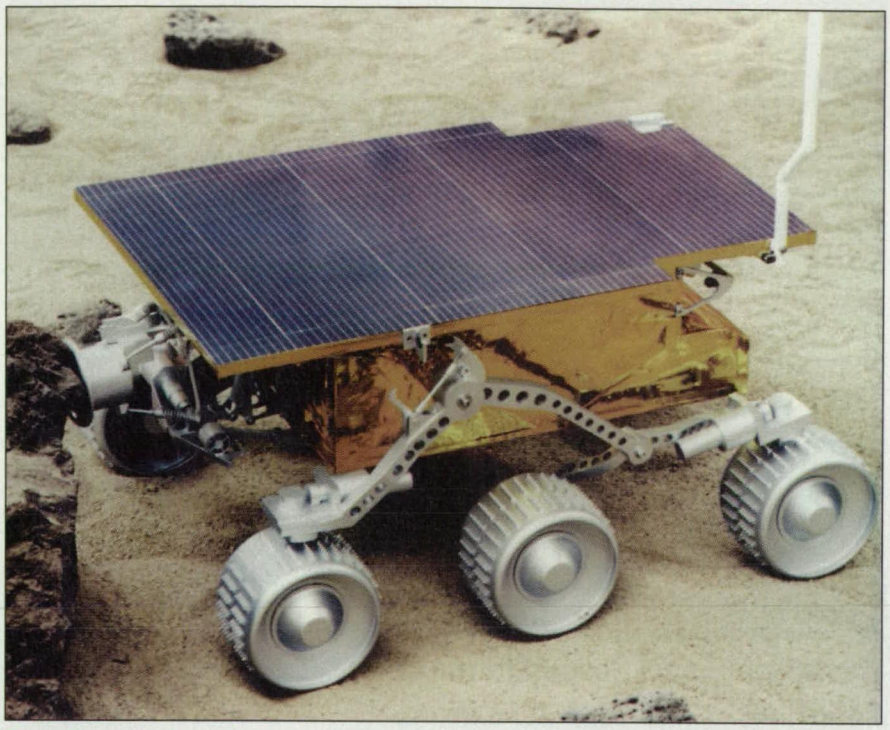
Helical springs machined from a single bar have found their way into many applications from the commercial to the Mars Pathfinder mission.

The storing of energy in mechanical spring-like devices started long ago, and today springs are everywhere around us, in scales, mechanical pens, valve closures, precision instruments, and so forth. Traditional springs such as wire-wound and Belleville washers fulfill many spring applications. But for designers with special and/or precise design requirements for their applications, a helical machined spring can be a very good solution.

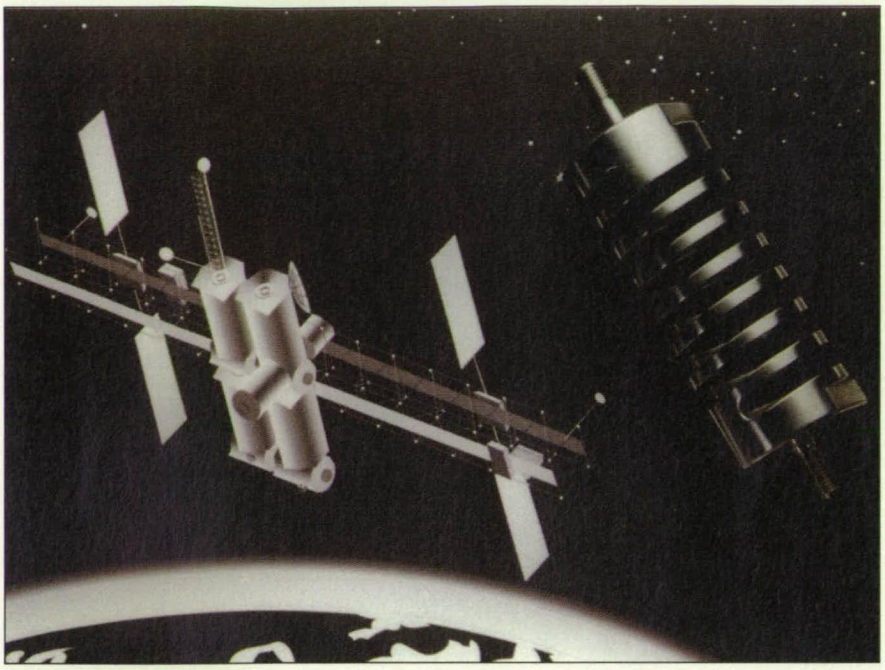
Helical Products Company has reinvented spring design by applying its HELI-CAL® Flexure technology, with its inherent versatility, to the design and manufacture of one-piece machined springs. The HELI-CAL Flexure is a flexible helix-curved beam machined from one piece of material. It can take the form of a precision spring, coupling, or U-joint, and can be manufactured into a wide variety of shapes and sizes for almost any application. To date, more than 20,000 unique machined Flexures have been created by Helical Products Company.

During the development of such a spring, the following criteria are normally considered:

- desired spring performance;



**The Pathfinder Sojourner rover used three Helical machined springs to position the Alpha Proton X-ray Spectrometer against a Mars rock.**



**The International Space Station will utilize Helical machined titanium springs in connector assemblies.**

- envelope size;
- integration of multiple features; and
- attachments.

The Helical machined spring combines the elastic properties of various high-strength materials, typically corrosion-resistant steels, aluminum, and titanium) with the curved-beam helix to provide precise deflection rates for compression, extension, torsion, lateral bending, and lateral translation-spring functions.

Because Helical's springs are machined for a specific application and purpose, there are no stock machined springs. Applied to either high-precision applications or commercially graded needs, the versatile HELI-CAL Flexure, used as a spring, provides superior elastic performance in a wide variety of applications. Machined springs can be designed to specifically address requirements for rate, reactions at desired deflections, combined rates, modal properties, weight, inertial limits, and more.

This application-specific approach facilitates an unusually good correspondence between what is desired and what is economically possible. Helical springs can also support such design objectives as reliability, repeatability, and multiple part integration.

Wire-wound springs and Helical's machined springs share many areas of common functionality. There are four venues, however, where the machine spring excels:

- integration of specifically desired attachments;
- pure couple reactions for torsional applications;
- wide variation of attachments for extension springs; and
- incorporation of multiple start configurations to eliminate extraneous reaction forces and moments.

The ability to integrate multiple features into a machined spring is another notable benefit. An integration of flanges, geometric shapes (squares, hexes, rounds, etc.), bearing seats, valve seats, gears, splines, bell-crank arms, internal and external threads, and other machinable shapes is available to the machined spring designer.

Wire springs provide only bent wire in the form of internal or external tangs for torsional spring attachments. Such a configuration is prone to high stress at the maximum bend of the attaching wire, plus, because of the configuration, the torque is the product of a force at a distance. Whenever torque is created by this technique, a resolution of the force is required. Machined spring attachments allow couples to be used to create the desired torque, and hence eliminate the need for force resolution.

Like the torsion wire-wound spring, the extension wire-wound spring is limited to a bent wire form (hoops and hooks) for attachment. Since nearly any machined form is available, the attachment for extension machined springs is limited by only the creativity of the design engineer.

In single-start springs used in compression or extension, whether they be wire-wound or machined, forces and moments in addition to the compression or extension forces are required to keep the springs at rest. Multiple starts, available only to machined springs, resolve these additional forces and moments within the given spring. The result is that ends of compression and extension springs naturally remain normal to the line of motion. Multiple-start machined springs are available in two, three, four, and five start configurations.

There are, certainly, cost differences between wire-wound and machined springs. The wire product can be produced complete in usually less than a minute of process time, which is many times faster than that required for machined springs. So, from a cost standpoint, the wire-wound product appears to be the spring selection of choice, and there are millions—likely billions—of successful wire-wound spring applications. In addition to the four direct benefits of machined springs cited previously, however, they can also allow for component integration, in which the reduction of overall part count reduces assembly time, conserves assembly space, and reduces inventory space and related purchasing activities and costs. Once designers become familiar with this concept, the many benefits of a multifeatured component become apparent. The HELI-CAL Flexure spring is a perfect foundation for integrating multiple features and functions into a single part.

Whether it be cross slots, double tangs, spline, bolt circles, flanges, geometric shapes, threads (internal or external) or simply machined flat ends, HELI-CAL machined springs provide a robust technical solution path to many elastic problems that are generally not solvable with tradition wire-wound springs.

For the Mars Pathfinder mission, NASA's Jet Propulsion Laboratory was charged with developing a Martian data-gathering vehicle that could deploy the Alpha Proton X-ray Spectrometer (APXS). The solution, the Sojourner rover, is a small radio-controlled cart that can roam around the surface of Mars, back up against a rock, and enable the APXS transducer head to align to the rock, radiate it, gather the reflected radiation, and determine the rock's composition.

This application required tight compliance of the transducer head to the rock surface. The most common way to accomplish a compliance motion is by using a gimbaled spherical joint, but this requires a clean sliding surface and is relatively heavy. One of the development engineers decided to try to fashion a totally elastic device. The plan was to use three Helical Products machined springs situated at the three corners of an equilateral triangle. The springs are subject dominantly to lateral bending, but small compression deflections are also possible. The HELI-CAL Flexure spring designed is made from 15-5PH CRES for an optimized weight of 6 grams.

Currently, Helical is building high-strength, Beta-C titanium springs to be used in connector assemblies in the International Space Station Alpha. These springs will be used dominantly in lateral translation, with launch for the components scheduled for 2001. Additionally, high-strength stainless compression and extension springs that each incorporate right- and left-handed Flexures are being readied for NASA's Shuttle Radar Topographical Mapper (SRTM) mission scheduled for launch in late 1999.

*For more information, contact Gary Boehm, senior research engineer, at Helical Products Co., 901 W. McCoy Lane, PO Box 1069, Santa Maria, CA 93456; (805) 928-3851; fax (805) 928-2369; www.Heli-Cal.com.*

# Thermal and Mechanical Effects in Graded Composite Cylinders

**In this theory, coupling between microstructural and macrostructural effects is taken into account.**

*Lewis Research Center, Cleveland, Ohio*

"HOTCFGM-1D" denotes a collection of four computer programs, plus the underlying theory, for calculating thermomechanical and inertial effects in axisymmetric cylindrical multiphase-composite-material objects that are functionally graded along their radial coordinates. The theory and programs are valid for the special case in which a thin cylindrical structural component is subject to macroscopically axisymmetric thermal and thermomechanical and inertial loads applied uniformly along its cylindrical axes.

The term "functionally graded" characterizes a class of materials, the microstructures of which are spatially graded to achieve specific thermal and/or mechanical properties. In the case of a multiphase composite material, functional grading can be effected by use of spatially variable spacing between individual fibers or other inclusions (see figure) and/or by use of inclusions of different properties, sizes, and shapes.

The "1D" in "HOTCFGM-1D" refers to the fact that the theory is a quasi-one-dimensional version of a more-general higher-order theory, currently under development. The one-dimensionality is a consequence of the shapes of objects and symmetry of loading conditions described above. One aspect of this one-dimensionality is that the overall deformation of an object is characterized by a constant average axial stress and strain.

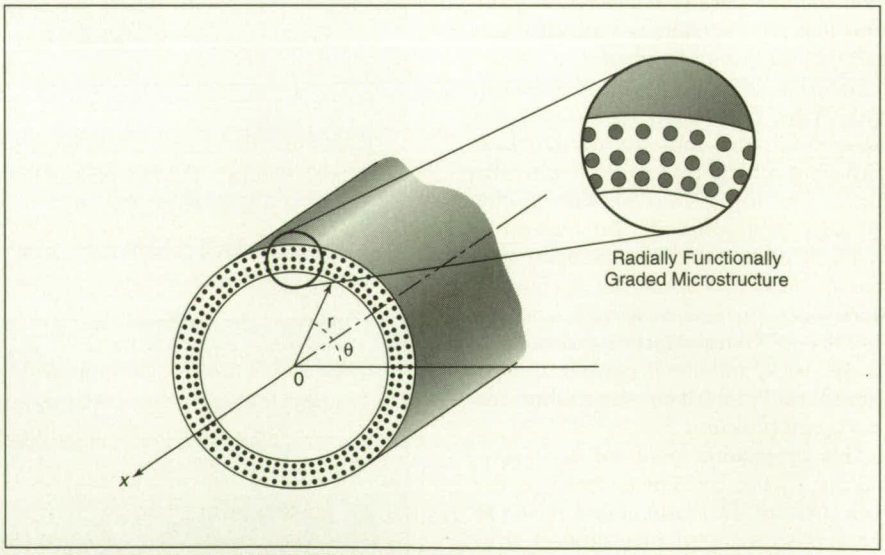
The one-dimensional higher-order theory was developed for use in the analysis, optimization, and design of axisymmetric cylindrical components of aircraft engines (e.g., combustor linings, rotor disks, and heat shields). The theory will enable designers to use functional grading to enhance the performances (e.g., deformation characteristics, resistances to thermal fatigue, and service lives) of such components. In the theory, coupling between microstructural and macrostructural effects in cylindrical bodies of revolution is explicitly taken into account for the sake of accuracy; in contrast, functionally graded objects cannot be analyzed accurately by following the older standard micromechanics approach based on the concept of representative volume-element mathematical models coupled with macrostructural-analysis models in a noninteractive manner.

The quasi-one-dimensional version of the theory includes representations of inertial body forces to account for effects of rotation. The theory also accounts for externally applied loads and radial temperature gradients. Applied loads and other boundary conditions can be in the form of temperatures imposed on the inner and outer surfaces, radial pressures, and/or radial displacements. The theory and computer programs can readily be modified by incorporation of constitutive theories of inelastic responses and of damage in constituent materials under nonisothermal conditions. At present, the computer programs include subprograms that implement the classical incremental theory of plasticity and the generalized viscoplasticity with potential structure (GVIPS) unified viscoplasticity theory. Three of the computer programs, called "fgmp.tube.f," "fgmp.homog.tube.f," and "fgm.gvips.tube.f," are research-oriented codes for investigating the effects of (1) functional gradings and (2) properties of multiphase reinforcements upon the temperature, stress, and inelastic strain field in thin shells subjected to axisymmetric thermomechanical and inertial loads. The user specifies the radial distribution of reinforcing material. The thermoelastic and inelastic properties of the individual phases can vary with temperature. The elastic phases can be isotropic; alternatively, they can be transversely isotropic with radial, circumferential, or longitudinal axes of symmetry. The inelastic phases can be modeled either by classical plasticity theory in fgmp.tube.f or GVIPS unified viscoplasticity theory in fgm.gvips.tube.f. A homogenization capability within fgmp.homog.tube.f admits the inclusion of heterogeneous phases.

The fourth computer program, called "fgmp.tube.opt.f," combines a major analysis module from fgmp.tube.f with a commercial optimization code called "DOT." The total optimization software package enables the user to identify radial distributions of reinforcing phases that minimize or maximize objective functions defined by the user; examples of such functions include internal moments or plastic strains.

*This work was done by Marek-Jerzy Pindera of the University of Virginia and Jacob Aboudi of Tel-Aviv University for* **Lewis Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Physical Sciences category.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Lewis Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Road, Cleveland, Ohio 44135.*
*Refer to LEW-16753.*




In the **Geometric Model of HOTCFGM-1D**, reinforcing phases are uniformly distributed in the axial and circumferential directions but arbitrarily distributed (for functional grading) in the radial direction. In this example, the reinforcing phases are axial fibers; in other examples, they could be circumferential fibers or discontinuous inclusions.

# Human-Powered Centrifuges and Stationary Exercise Stations

**Selectable modes of operation include constant speed, constant torque, and freewheeling.**

*Ames Research Center, Moffett Field, California*

Human-powered machines that can be operated as centrifuges or as stationary exercise stations have been invented. These machines are suitable for a variety of terrestrial and outer-space applications that involve physical therapy, maintenance of physical fitness, centrifugal simulation of gravitation or acceleration, and/or measurement of physiological responses to exercise and centrifugation. A machine of this type can be operated in any of several selectable modes, in which one or more human participant(s) can be active or passive and in which the speed of rotation (and thus the centripetal acceleration), the human-generated torque, or the human-generated power can be regulated. Although the basic concept of human-powered centrifuges for such applications is not new, older designs for machines of this type do not provide for such a variety of operating modes.

One machine of this type (see Figure 1) includes recumbent seats for two riders on a turntable, plus a stationary seat near the turntable. A bicycle-type pedal-crank mechanism is located at each seat. The turntable can be powered by either or both riders and/or by a person on the stationary seat, by use of the bicycle-type mechanisms. Each bicycle-type mechanism includes a ratchet-type clutch to provide for freewheeling when the person using the mechanism elects not to pedal.

When rotated by human power, the pedals at either rider seat impart rotation to the turntable hub through a drive train that includes sprockets and chains that drive a pinion that meshes with a bevelled crown gear on the hub. Similarly, when rotated by human power, the pedals at the stationary seat impart rotation to the turntable hub through a drive train that includes sprockets and chains that drive a pinion that meshes with another bevelled crown gear on the hub.

Optional equipment includes a video camera, physiological monitoring equipment, and data-transmission equipment. Data from the monitoring equipment can be transmitted through slip rings and wires to an external computer system.

Figure 2 depicts a different machine of this type. For clarity of illustration, only one rider station is shown on the turntable, though in general there could be more than one. Also for the sake of clarity, the seat is not shown. As before, the rider supplies power via a bicycle-type mechanism. The pedal crank drives an automatic transmission that includes a ratchet-type clutch for freewheeling. The automatic transmission adjusts the gear ratio between the rider and the turntable and maintains constant rider power demand. The power output from the automatic transmission is sent through a flywheel friction brake and through a slide collar to the output shaft connected to the turntable hub. The slide collar is used, when needed, to disengage the output shaft to enable the rider to exercise while the turntable remains stationary. The flywheel friction brake is adjustable to absorb extra energy supplied by the rider and not needed to turn the turntable. The flywheel also provides smooth pedaling, especially when the output shaft has been disconnected for stationary operation.

*Continued*

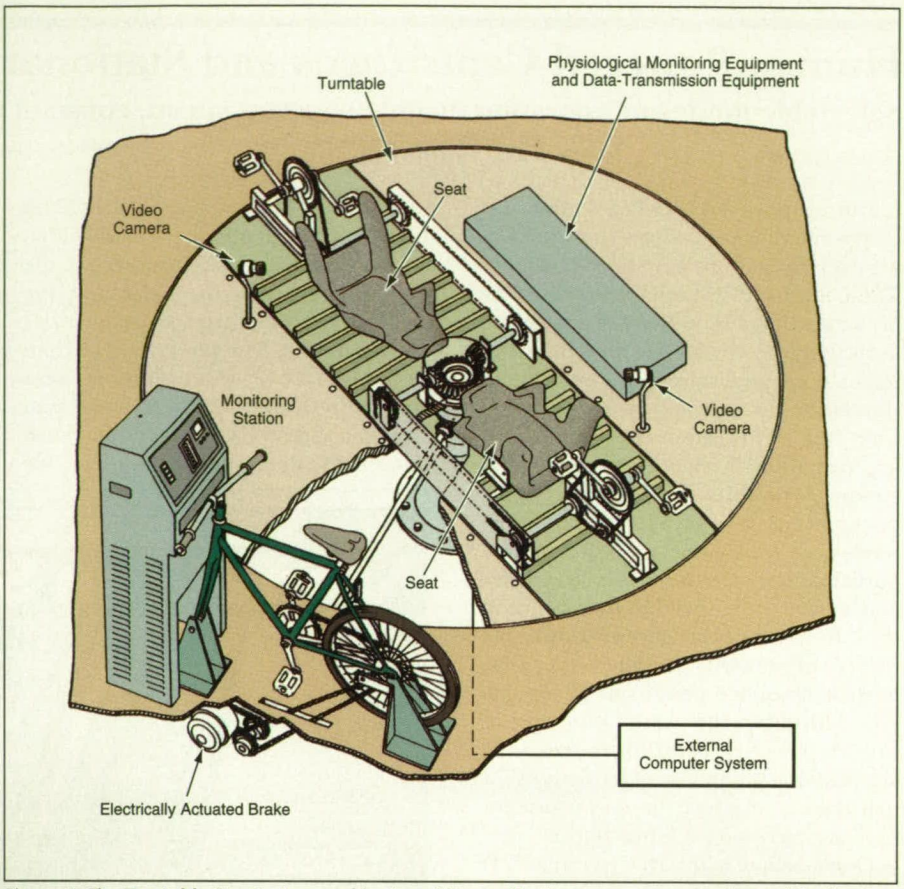



Figure 1. The **Turntable Can Be Powered** by two riders and/or by a person on a stationary bicycle-type mechanism. The electrically actuated brake resists the pedalling effort with a controlled torque.



Human-powered machines that can be operated as centrifuges or as stationary exercise stations have been invented. These machines are suitable for a variety of terrestrial and outer-space applications that involve physical therapy, maintenance of physical fitness, centrifugal simulation of gravitation or acceleration, and/or measurement of physiological responses to exercise and centrifugation. A machine of this type can be operated in any of several selectable modes, in which one or more human participant(s) can be active or passive and in which the speed of rotation (and thus the centripetal acceleration), the human-generated torque, or the human-generated

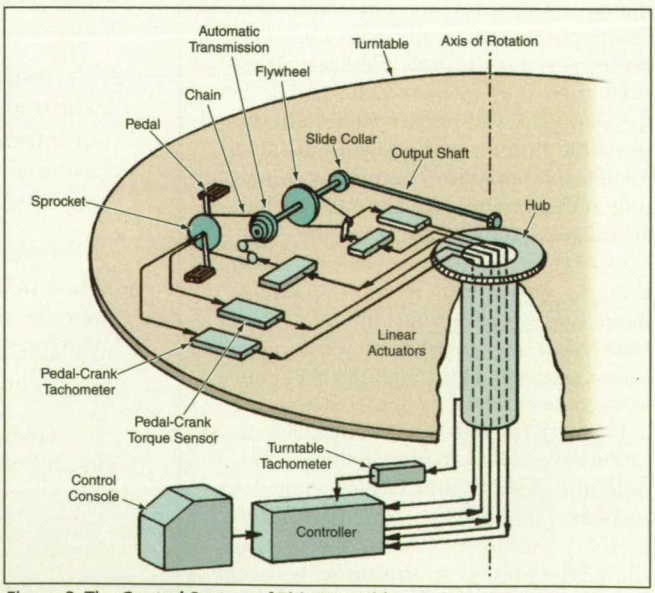



Figure 2. The **Control System of This Turntable** regulates the power demand on the rider, the torque applied by the rider, or the speed of rotation.

adjusting the tension on the strap and selecting the gear ratio on the automatic transmission.

The tension on the strap is measured and fed back to the controller, which then commands the second-mentioned linear actuator to adjust the tension. The output of a turntable tachometer is used as a feedback signal for regulating the speed of rotation and thus the centrifugal force, which can be preset and changed as desired prior to or during operation. The workload or power output required of the rider can be preset and maintained at a constant level independent of the speed of rotation. For operation at a constant speed of rotation, the turntable can be accelerated up to the preset speed but cannot be made to turn any faster, regardless of additional rider effort: this is accomplished through a feedback subsystem that causes excess power to be diverted to storage or dissipated.

*This work was done by Gerald M. Mulenburg and Joan Vernikos of* **Ames Research Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Machinery/Automation category.*

*This invention has been patented by NASA (U.S. Patent No. 5,616,104). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center [see page 20].*

*Refer to ARC-12058.*

# Mobile System for Control of a Remote Rocket-Launching Range

## A single unit replaces multiple units that had to be connected to each other on range.

*Goddard Space Flight Center, Greenbelt, Maryland*

The Wallops Flight Facility of the Goddard Space Flight Center has designed and built in-house a Mobile Range Control System (MRCS), which is a self-contained system to be deployed in support of rocket launches at remote ranges in cases in which termination of flight may be required for safety purposes. The MRCS includes data-acquisition subsystems, real-time data-computation subsystems, range-safety displays, command/destruct transmitters, and supporting communication subsystems, all together providing for remote range control.

Prior to the development of the MRCS, subsystems in several mobile containers were integrated on range to satisfy requirements to provide functions similar to those now performed by the MRCS. In comparison with the older collection of subsystems in separate containers, the fully integrated MRCS can be tested more completely prior to shipment, and it reduces mission-support time and cost. Improvements incorporated into the MRCS include state-of-the-art hardware and real-time software data processing which generates and displays range safety real-time instantaneous impact prediction data derived from mobile radar and telemetry tracking systems. The MRCS provides safe and reliable conduct of Expendable Launch Vehicles (ELVs) and an environment that is comfortable for operators.

*This work was done by H. Dean Price of* **Goddard Space Flight Center.** *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Electronic Components and Systems category.*

*GSC-14021*

# New Products

## Digital Brushless Servo Amplifiers

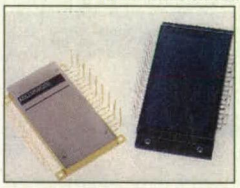
Cleveland Motion Controls, Pittsburgh, PA, says that its ACS1335 and ACS1350 single-axis digital brushless servo amplifiers have digital front ends using PC menu-driven software and repeatable adjustments of all servo parameters for easy integration into a motion control system. Synthesized encoder outputs up to 1024 pulses per-revolution provide the user with smooth operation at low speeds and high positional accuracy, the company says. The amplifiers can be used in either torque or velocity modes. The ACS 1335 is rated at 12.9 kW and the ACS 1350 at 17.9 kW; continuous current rating for the former is 35 A and for the latter 50 A.

**For More Information Circle No. 760**

## Small Brushless Servo Motor

MTS Automation Custom Servo Motors, New Ulm, MN, has added the 1½ inch motor to its MaxPlus® motor line. Designed for use in applications where size and weight are critical, they operate at 5000 rpm with up to 30 oz.-in. of continuous stall torque. MTS says that the use of neodymium iron boron magnet material results in a design that typically generates 20 percent more torque than conventional motors of similar size. Innovative insulation techniques and higher-density windings also help increase torque, according to the company, and the motor's low inertia results in faster acceleration.

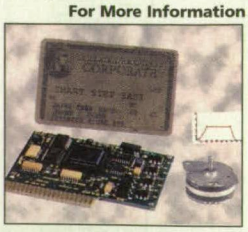
**For More Information Circle No. 763**



## Hybrid Servo Amplifier

The BLH series hybrid servo amplifier from Kollmorgen, Radford, VA, provides the highest ratio of output power to volume for driving DC brushless motors, the company says. Available in plastic and hermetic packages, they offer continuous power ratings of 540 to 1070 V in nominal bus voltages of 24, 28, 70, and 270 V DC. In the hermetic package, the BLH, measuring 3.1" × 2.1" × 0.38", operates in -55 to +70 °C and withstands 50-g vibration, 1500-g shock, and 100 percent relative humidity. Additional features include adjustable pulse width modulation frequency and full four-quadrant control.

**For More Information Circle No. 766**



## Driver and Controller Board

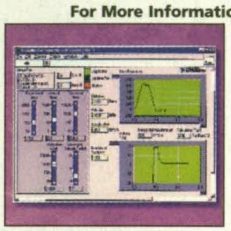
The DCB-25 driver and controller board from Advanced Micro Systems Inc., Nashua, NH, have been designed specifically for use with small stepper motors. The device includes a microprocessor, memory, serial command input and 0.25-A unipolar drivers. Also offered is the DCB-25-2, a 2-A version. The company says that programming and application design is simplified by the DCB-25's repertoire of more than 30 robust motion commands. Standard I/O includes six general-purpose ports, jog, limit, and home sensor inputs.

**For More Information Circle No. 769**

## Software and Motion Control

Aerotech Inc., Pittsburgh, PA, announces that PC-based computer numerical control is now available with its U600MMI software combined with the UNIDEX 600 PC-based motion controller. Traditional G- and M-code programming is supported, and the system supports standard CNC functions as well as advanced functions such as manual feedrate override, manual spindle feedrate override, cutter compensation, lookahead, retrace, cylindrical and polar coordinate transformations, parts rotation, mirroring, normalcy, dry run, and machine lock. Multitasking allows for "PLC" task and multiple machining cells. A built-in editor is included for editing and loading programs.

**For More Information Circle No. 761**



## Add-On Toolkit for Motion Control

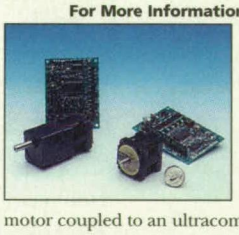
National Instruments, Austin, TX, offers a new version of its ValueMotion™ add-on toolkit for integrating motion control with the company's LabView graphical instrumentation software. The company says that with the Value Motion VI Library revision, a user can implement the full command set of motion control functions for its ValueMotion servo and stepper control boards in LabView. The ValueMotion software includes high-level example and functional application VIs for setup, initialization, and multi-axis system control.

**For More Information Circle No. 764**

## Low-Horsepower Motor Drives

The new CompAC variable speed motor drives from ABB Drives & Power Products, New Berlin, WI, cover a power range from 0.5 to 50 horsepower. The family includes the ACS 100, rated for speed control of motors ranging from 0.5 to 3.0 HP, at 230 V, single- or three-phase; the ACS 140, rated for motors from 0.5 to 3 HP, 230 V AC and 460 V AC, in single- and three-phase; and ACS 400, available in a NEMA 1 enclosure with a NEMA 12 option and in two models, one to operate motors from 3-30 HP at 200-240 V AC, and the other for motors from 3-50 HP at 380-480 V AC. ABB says the built-in PID controller software eliminates the cost of an external controller.

**For More Information Circle No. 767**



## Five-Phase Step Motor/Driver

Oriental Motor U.S.A. Corp., Torrance, CA, introduces what it calls the world's smallest 5-phase hybrid stepping motor coupled to an ultracompact driver. The Vexta® PMC package produces holding torque levels from 4.7 oz.-in. for the PMC33A3 (1.1" square by 1.22" long) and 8.5 oz.-in. for the PMC35A3 (1.1" square by 2.0" long). The motors weigh 0.22 and 0.37 lbs. respectively. The compact driver, 2.2" wide × 2.83" long × 0.47" high, runs on 24 or 36 V DC. Available with gearheads, these geared step-motor packages develop running torque ranging from 10 oz.-in. for the PMC33B1-MG3.6 to 70 oz.-in. for the PMC35B1-MG30.

**For More Information Circle No. 770**

## CNC Vertical Machining Center

The S-1050 "Shark" CNC machining centers from Clausing/Kondia, Kalamazoo, MI, are heavy-duty high-speed precision systems, the company says. They offer 40" × 20" × 20" XYZ-axis travel, an 18-position automatic sequential/bidirectional tool changer with a 6-second change time, Fanuc OMC control and Fanuc axis and spindle drives. It is available with a choice of 4000-, 6000-, or 8000-rpm spindle speeds. Positioning accuracy is ±0.0004"; repeatability is ±0.0002". The company says that though the Shark is engineered for large heavy production applications, it is flexible enough for any size job.

**For More Information Circle No. 762**

## Linear Actuator with Parallel Motor

MSI Technologies LLC, Englewood, CO, an Automation Solutions International company, introduces the Express 180° linear actuator with parallel motor. It features precision ball screws for smooth, quiet motion, MSI says, as well as high repeatability and heavy load and movement capacities in a variety of applications. The user may choose a stepper or servo motor, either of which can be mounted on the left, right, top, or bottom of the actuator. All actuators are repeatable to ±0.010 mm. A variety of travel lengths and performance options are available.

**For More Information Circle No. 765**

## DSP-Controlled Servo Drives

UltraDrive/Westamp, Chatsworth, CA, a division of ORMEC Systems Corp., announces the G Series, utilizing digital signal processors (DSPs) that are specifically designed for motor control to deliver high-performance servo control with digital technology. The company says the drives provide 1/T velocity loop or torque-mode control, true performance matching with motor RMS horsepower modeling, and extremely low torque ripple. The series offers pulse-width-modulated switching frequencies from 10-20 kHz and current loop bandwidths from 1-2 kHz. Four models deliver from 5 to 20 A continuous current output from 1.2 to 4.8 kW.

**For More Information Circle No. 768**

## Variable Speed Motor

Reliance Electric, Milwaukee, WI, expands its line of RPM AC variable speed motors with the RPM AC 180, a frame motor the company says brings an advanced variable-speed motor design to users with tight space requirements and high motor performance standards. With the introduction of the 180 frame motor the RPM AC line is now available from ¼ horsepower to 1000 horsepower, and in frame sizes from 56 to 4460. All RPM AC motors utilize a Class H insulation system to provide high mechanical and thermal strength. The system has been designed and tested for compatibility with pulse-width-modulated controllers.

**For More Information Circle No. 771**

# Software for Minimizing and Removing Burrs in Manufacturing

**The overall costs of manufacturing precise components would be reduced.**

*Lewis Research Center, Cleveland, Ohio*

An integrated suite of computer programs is undergoing development to address issues pertaining to the formation of burrs — undesired projections of metal that are generated on edges of workpieces in most metal-cutting operations. Burrs must be removed prior to assembly of machined workpieces, and therefore, plans for manufacturing must usually provide for deburring operations. The developmental software is intended to provide capabilities to (1) predict and minimize the formation of burrs and (2) plan deburring operations to maximize deburring performance and thereby reduce the overall cost of the design-to-fabrication cycles of precisely machined components.

One of the two main programs in this software system is called "BurrEXPERT." With the help of a commercial computer-aided-design (CAD) program as an interface, the BurrEXPERT accepts a drawing of a three-dimensional part (see figure) and assesses the burr-formation potential of the design features of the part under various manufacturing-process plans. The prediction capabilities are driven by a burr-property knowledge base and known burr relationships. These relationships are based on types of manufacturing processes, process parameters, properties of materials, and interactions among part geometries, tool geometries, and tool paths. By interactively and iteratively predicting the sizes, shapes, and locations of burrs, users can plan machining and edge-finishing processes, thereby shortening the design-to-fabrication cycle.

The other main program in this system is the Deburring Expert (DEXTER). When fully developed, the DEXTER will guide the user in selecting candidate edge-finishing processes, by use of a decision strategy driven by a deburring knowledge base. Using predicted observable burr attributes of a part, the DEXTER will match the capabilities and limitations of deburring processes to the characteristics of the part, the burrs on the part, and the desired edges on the part. The DEXTER will evaluate the overall applicability of the processes in the deburring knowledge base to the features on the part. Upon completion of its evaluation, the DEXTER will present a selection of candidate deburring processes. The user can then choose to examine still images, multimedia video images, and animations to obtain detailed information about each candidate deburring process.

Ultimately, the BurrEXPERT will be integrated with the DEXTER to form the Edge Finishing Master software package, so that reasoning about strategies for the prediction and minimization of burrs can be integrated directly with reasoning about the burr-removal process. The Edge Finishing Master will thus serve as a "seamless" edge-finishing software tool for use by design and manufacturing engineers at all levels of integration between design and manufacturing functions, including the highest level of integration, where the outcome of manufacturing of parts is simulated during the design stage. High levels of integration between design and manufacturing will enable designers to perform computational simulations to achieve optimal balances between opposing metrics (e.g., surface finish vs. total cost of production).

*This work was done by Julie M. Stein, Andrew Chang, and David Dornfeld of Integrated Constructs, Inc., for* **Lewis Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Manufacturing/Fabrication category.*

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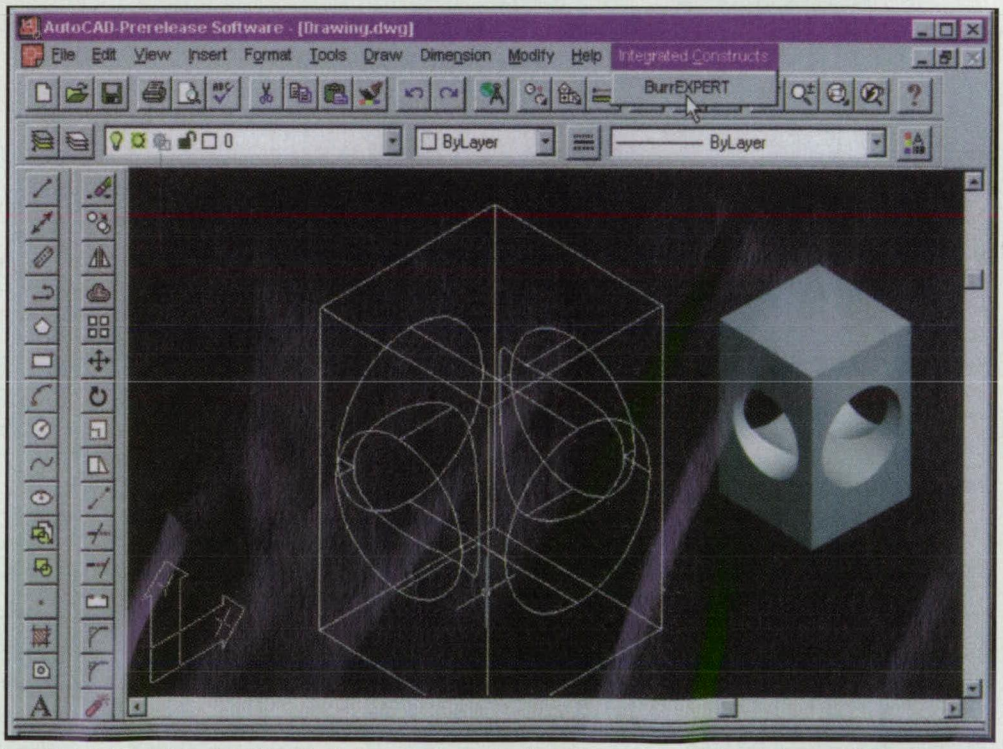



In a **Typical Use of the BurrEXPERT**, the user seeks to predict and minimize the burrs that would be formed in drilling intersecting holes in a block destined to become a valve body. As development continues, DEXTER (and eventually other software "experts") will be selectable from the menu.

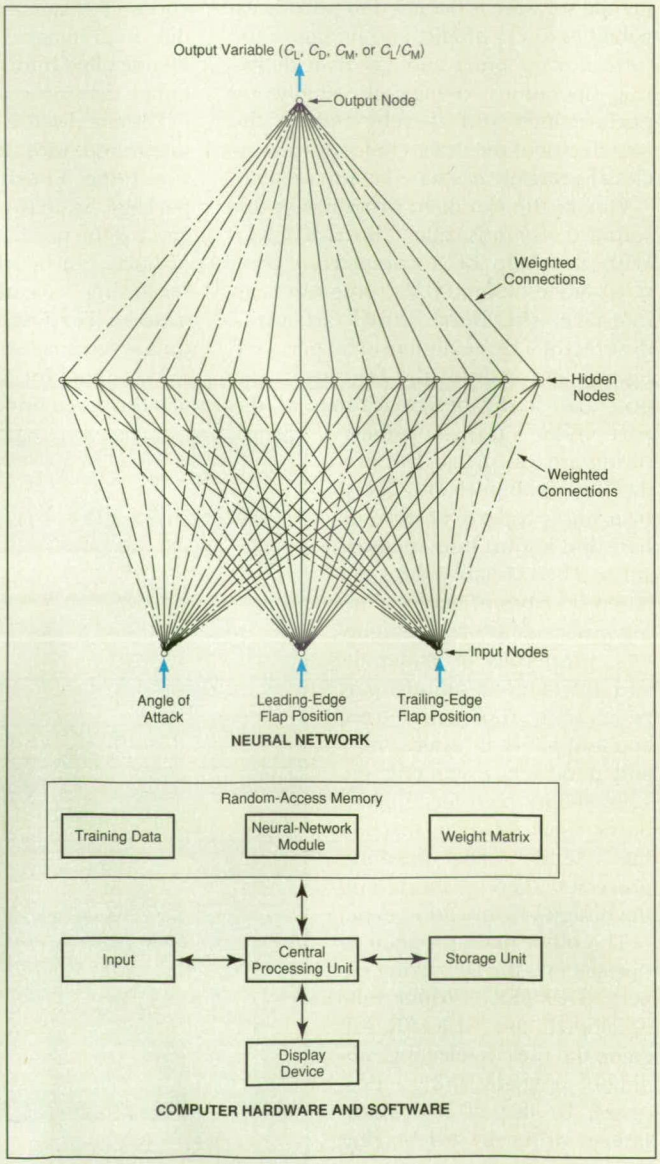
# Neural-Network Modeling of Flow Properties of an Object

## Wind-tunnel testing time can be reduced.

*Ames Research Center, Moffett Field, California*

A method of computational simulation of the aerodynamic- or hydrodynamic-flow performance features of objects involves the use of neural-network mathematical models implemented in computer hardware and software. The method can be applied in conjunction with wind-tunnel, water-tunnel, or water-trough testing of scale models of such diverse objects as aircraft or parts of aircraft, sails, fins, turbine blades, and boat hulls.

In the case of an aircraft, for example, a neural network can be trained from (1) test input signals (e.g., positions of control surfaces; angle of attack; angles of roll, pitch, and yaw; power settings; and airspeed) and (2) test output signals (e.g., lift, drag, pitching moment, and/or other performance features). In general, the relationships between the input and output variables are nonlinear. The present method harnesses the ability of neural networks to learn nonlinear relationships between input and output variables.




A **Neural Network** for modeling selected aerodynamic characteristics of an airplane is implemented in computer hardware and software.

A neural-network model can be used to perform the nonlinear interpolation or extrapolation needed to predict the output variables for previously untested combinations of input variables. Moreover, the neural-network model can be generated during a wind-tunnel test, and its predictions used immediately to focus the test conditions on input-variable combinations that have the greatest engineering significance; for example, the predictions can be used to "zero in" on control-surface settings that result in maximum lift. Thus, the method can reduce wind-tunnel test time, which can be expensive (≈$6,000/h in a large wind tunnel).

The figure illustrates the application of the method to a subset of the aerodynamic characteristics of a model airplane in a wind tunnel. The neural network includes an input layer containing three nodes (one for each of three input variables), a hidden layer containing 15 nodes, and a single output node. The input variables are the angle of attack, the leading-edge flap position, and the trailing-edge flap position. The output variable could be the coefficient of lift ($C_L$), the coefficient of drag ($C_D$), the coefficient of pitching moment ($C_M$), or the lift-to-drag ratio ($C_L/C_D$). This neural network is a relatively simple one, chosen for the sake of clarity in illustrating the method; in a practical application, there could be more than three input nodes and variables, more or fewer than 15 hidden nodes, and multiple output nodes and variables.

Each hidden node is connected to the output node and to the input nodes. The signal transmitted along each connection is proportional to a weight or strength (which is represented in software as one of the elements of a weight matrix). Thus, the input to each hidden node is a weighted sum of the outputs of the input nodes, while the input to the output node is a weighted sum of the outputs of the hidden nodes. The output of each node is a function (denoted an "activation" function) of its input; typically, the activation function is a sigmoid function like a hyperbolic tangent. A neural-network module in the software implements the activation function.

In the training process, the neural network is presented with sets of input variables and corresponding output variables from wind-tunnel tests. The connection weights are adjusted in an iterative subprocess in an effort to make the neural-network outputs approach the correct values of the output variable.

The learning problem to be solved in the iterative subprocess can be characterized as an optimization problem: One seeks connection-weight values that are optimum in the sense that they minimize some measure of the error in the neural-network outputs; e.g., the sum of squares of the differences between the neural-network outputs and the correct values of the output variable for all training sets. If training set is relatively small (no more than a few hundred data points), the learning problem is best solved by the Levenberg-Marquardt method. The training process is terminated when the error measure falls below a specified low level or a specified maximum number of iterations is exceeded.

*This work was done by Charles Jorgensen and James Ross of* **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

*This invention has been patented by NASA (U.S. Patent No. 5,649,064). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14008.*

# Diagnosing Rotating Machinery Using Spectral Distribution Functions

## Spectral distributions of vibration signals can reveal changes indicative of damage.

*Ames Research Center, Moffett Field, California*

A method for detecting and characterizing faults in a rotating machine involves analysis of selected aspects of the evolution of the spectral distribution function (SDF) of its vibrations. The method is based on the proposition that long-term accumulation of damage (e.g., bearing wear or spalling of gear teeth) is accompanied by long-term changes in the SDF, and that these changes are revealed as differences among SDFs computed from short-observation-time vibration data. Data displays produced according to older vibration-analysis methods, including methods based on the conventional power spectral density (PSD), tend to display large components of random noise and other artifacts that often make interpretation difficult. The present method based on the SDF gives more robust indications of changes, yet entails little more computation than do methods based on the conventional PSD.

The SDF is derived from the PSD. It is a monotonically increasing function that bears the same relation to the PSD as a cumulative probability distribution to the probability density function.

Consider a vibration signal $X(t)$, where $t$ is time. Let $X(t)$ be sampled at intervals of $\Delta t$ to obtain the time series $X_j = X(j\Delta t)$, where $j$ is an integer. Let the time series comprise a total of $N$ samples. Let the time series be transformed as

$$C_k = \sum_{j=1}^{N} X_j e^{2\pi i(j-1)(k-1)/N}$$

for any integer $k$ from 1 to $N$. The periodogram representation at $M = (N/2) + 1$ points is given by

$$S_k = \frac{C_k C_k^*}{N^2}$$

for $k = 1$ or $M$ and

$$S_k = \frac{\left(C_k C_k^* + C_{N+2-k} C_{N+2-k}^*\right)}{N^2}$$

for any integer $k$ from 2 to $M - 1$, where the superscript asterisk denotes the complex conjugate. This representation is an $M$-line discrete estimate of the power spectral density, for frequencies $f_k = (k-1)/(N\Delta t)$.

The sum of all terms in the periodogram is the mean-square amplitude of the time series — a measure of the total signal energy. The spectral distribution function (SDF) in this situation is defined as the partial sum

$$F_k = \sum_{j=1}^{k} S_j$$

for any integer $k$ from 1 to $M$. Thus, $F_M$ is the mean-square amplitude, and $F_k$ is an estimate of the energy at and below frequency $f_k = (k-1)/(N\Delta t)$. The SDF can be normalized by $F_M$, to obtain a normalized spectral distribution function (NSD) that is an estimate of the fraction of energy at and below a given frequency.

The method was applied in a test case involving vibration data from a helicopter tail-rotor gearbox. Data were taken under three conditions that might be encountered in a long-term progression of damage; (1) a baseline condition (no faults), (2) spalls on two gear teeth,

and (3) half of one gear tooth removed. For each test condition, the vibration measurements were digitized and phase-averaged with respect to shaft rotation, then $N = 46{,}880$ samples were acquired at a rate of 46,880 Hz (thus making the observation time 1 second).

Figure 1 shows the PSDs and NSDs for the three test conditions. The PSDs are characterized by a few tones rising above background noise. Although there are differences among the PSDs, they are difficult to identify by casual visual inspection. The differences among the NSDs are more obvious and are easily quantifiable. The discrete jumps in the NSD indicate the tones, while the finite-sloped portions indicate the buildup of frequency-dependent continuous random noise.

The quantifiable indicators in the NSD are the frequencies that bound specified relative energy levels; for example, the first and ninth deciles are marked by the dashed lines in Figure 1. A more meaningful way to display these indicators is to juxtapose and join plots of the frequencies, parameterized by the relative energy levels, for sequential observation times. The resulting combination of plots (see Figure 2) amounts to a contour plot of constant relative energy levels in frequency-time space. Such contour plots are simple and easy to read, and can be stored for use in subsequent diagnoses.

*This work was done by Sanford Davis of* **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

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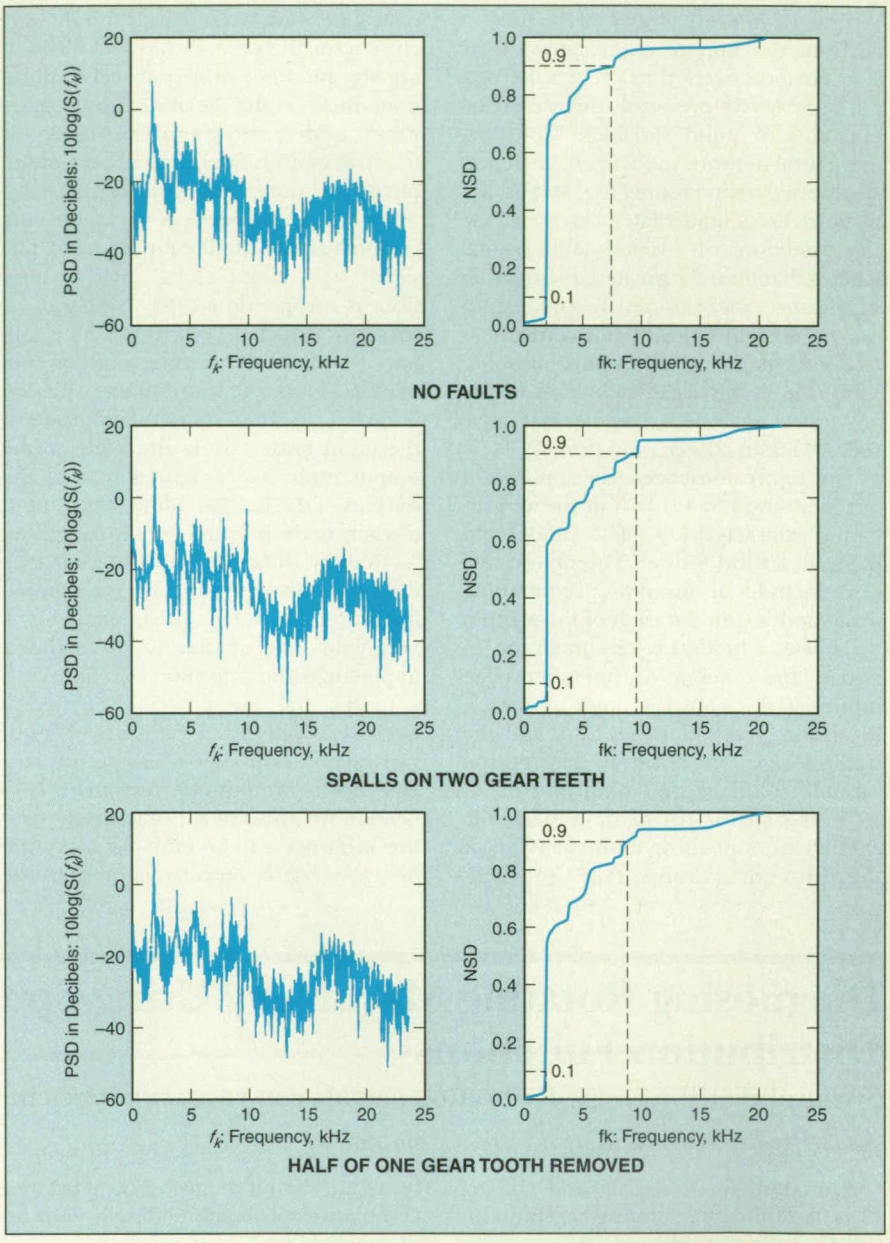


Figure 1. **PSDs and NSDs** were computed from vibration data acquired under three test conditions. Spectral changes associated with damage can be seen more easily in the NSDs than in the PSDs.

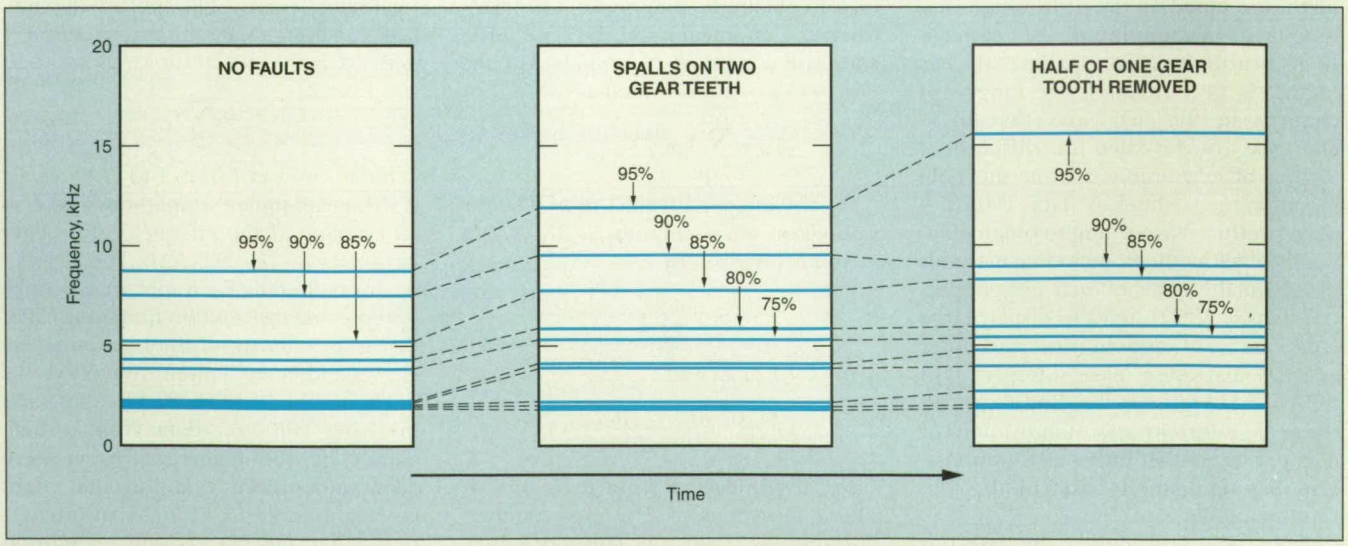


Figure 2. This **Contour Plot of Relative Energy Levels** was generated from the NSDs of Figure 1. Changes associated with damage can be seen even more easily than in the NSDs.

# Algorithm Accelerates Solution of Digraph Reliability Models

## Computing times are reduced from days to minutes.

*Ames Research Center, Moffett Field, California*

The SourceDoubls algorithm efficiently solves for singletons and doubletons of a digraph reliability model (defined below). In the case of a complex system of hardware and/or software represented by a correspondingly complex digraph reliability model, it can take as long as days to compute the solution by older, matrix-based methods. In contrast, SourceDoubls finds the solution in minutes, opening the possibility of using a digraph model for real-time monitoring and diagnosis of the system.

A digraph model (see Figure 1) is a graphical combinatorial failure-space model of a system, comprising nodes and AND gates connected by directed edges. Each node represents a piece of hardware or software, a mode of operation, a human action, or other component or aspect of the system wherein a failure could occur. Each directed edge represents a physical connection and/or functional dependence through which the occurrence of a failure can flow through the system to cause failure at another node. If a node is marked "failed," then the failure is deemed to propagate along the output edge(s) of the node to any connected node(s). The model can include directed loops that represent cycles. The model can be derived fairly straightforwardly from a schematic diagram of the system augmented by knowledge about the design of the system and modes of failure of components.

A common operation performed on a digraph model is the calculation of single failures and pairs of failures that could cause a target failure event to occur. A single failure that causes the target failure event is called a "singleton" of that event. Two failures that combine (as represented by use of an AND gate) to cause a target failure event are said to constitute a "doubleton" of that event. Finding singletons and doubletons for a digraph model is useful for finding weak links in the system and for quantitative estimation of the reliability of the system. Singleton and doubleton solutions can also be used in diagnosing the system because they indicate possible causes of failure events.

The SourceDoubls algorithm solves for the singletons and doubletons of all the nodes in a digraph model of a system by use of object-oriented programming concepts (see Figure 2). Each node, AND gate, singleton, or doubleton is stored as an object in computer memory. Each node or AND-gate object includes a number of slots to represent such data as the identity of the object, its input(s) and output(s), and its singleton(s) and doubleton(s). One of the slots is the mark slot, which contains a datum (1 or 0) that indicates whether a failure has or has not propagated to the node or AND gate. The input and output slots contain lists of pointers to nodes and AND gates directly connected to a given node or AND gate. The singletons slot contains information on the identities of the nodes associated with singletons of the given node, while the doubletons slot contains a list of pointers to doubleton objects. A doubleton object contains slots that point to the two nodes (objects) that are members of the doubleton, plus flags that indicate whether information on the doubleton has been printed or processed yet.

SourceDoubls finds singletons and doubletons in source operations:

- In the case of a singleton, a node of interest is marked as failed and the mark is propagated through the directed edges of the digraph to determine which other nodes can be expected to fail as a result. The node of interest is thus determined to be a singleton of each of the other failed nodes. The singleton calculations are completed before starting the doubleton calculations.
- The doubletons of a given node are found by searching for the doubletons for all the AND gates directly upstream of the node. This is accomplished in a limited source operation on each AND gate in the digraph. In this operation, the mark is allowed to travel only to nodes and not through AND gates. After this operation, the AND gate is added to the list of upstream AND gates of each node that the mark reached in the operation.

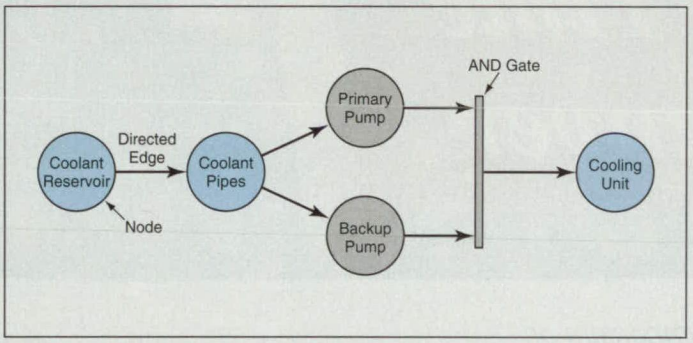


Figure 1. This Is a **Digraph (Directed-Graph) Representation** of reliability of a cooling system. Each node (circle) represents a failure in a component of the system. Each directed edge represents both a flow of coolant and a path of propagation of failure. The vertical bar represents an AND gate, which is used here because both the primary and backup pumps must fail in order for the cooling unit to fail for lack of coolant.

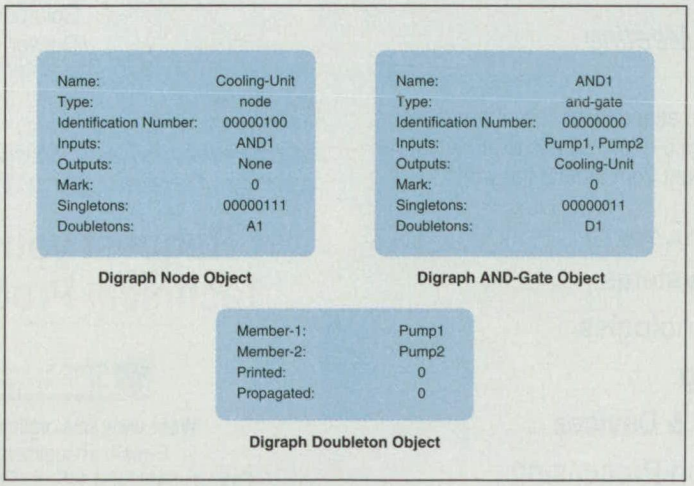


Figure 2. Nodes and AND Gates are represented by programming objects that contain data on identity, condition (failed or not failed), and connectivity.

The foregoing description is simplified for the sake of brevity. The algorithm also includes provisions for finding hidden doubletons, increasing computational efficiency by avoiding redundant calculations, and avoiding infinite computational loops when cycles are encountered.

*This work was done by D. L. Iverson and F. A. Patterson-Hine of* **Ames Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com*** *under the Information Sciences category.*

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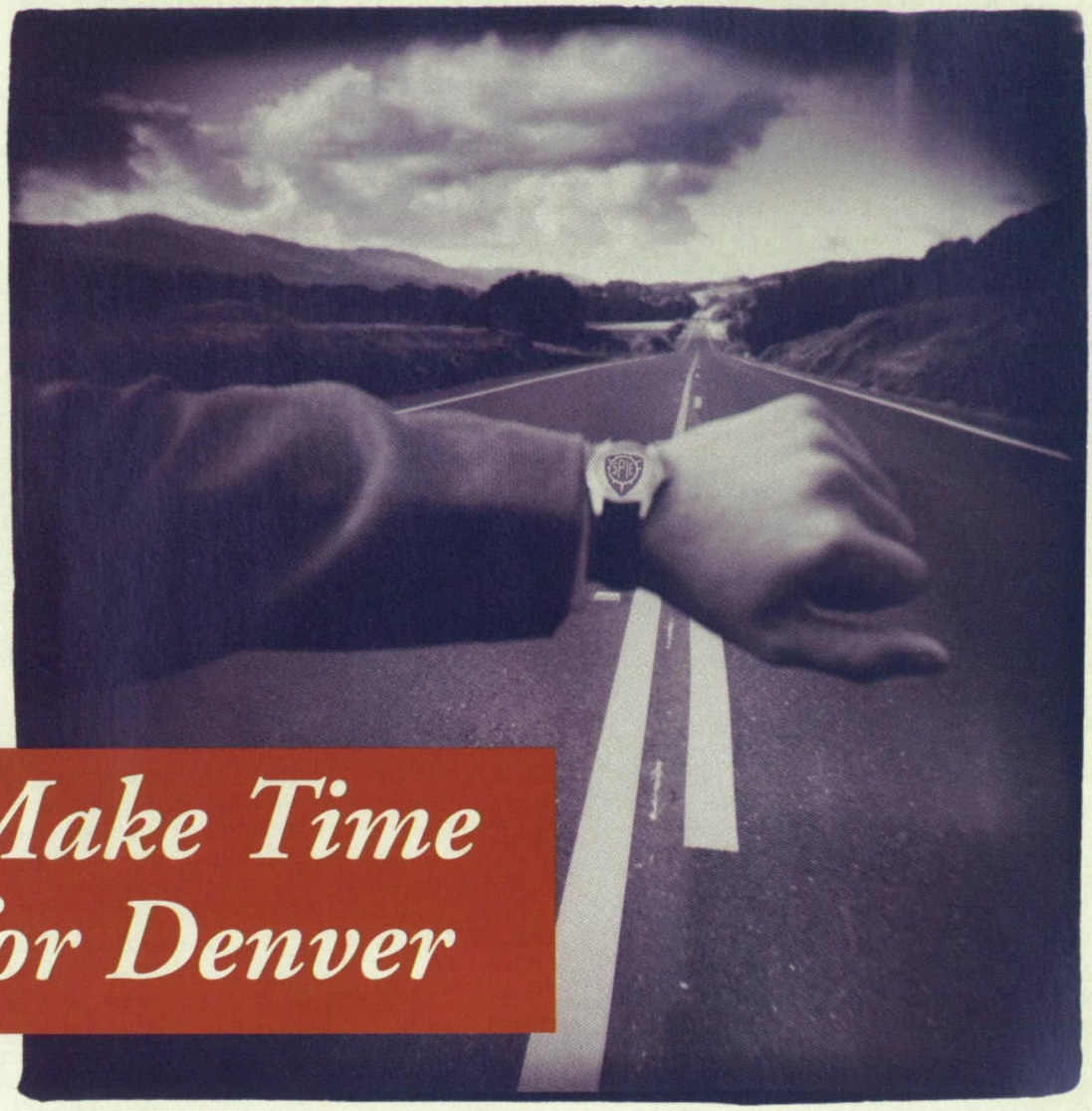

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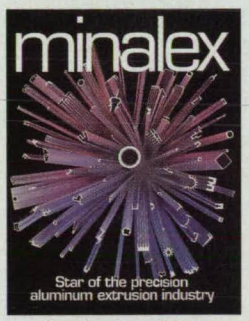


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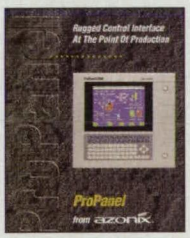


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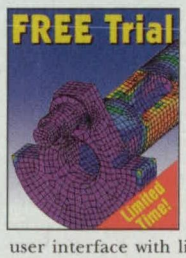


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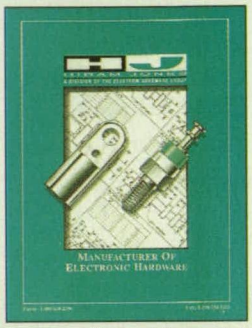


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## SEASTROM MACHINING DIVISION EXPANDS

Seastrom Machining Division has expanded their capabilities to include short- to long-run machined products utilizing Swiss & automatic screw machines, CNC lathes, and CNC vertical milling 4-axis. Seastrom is capable of turning precision metallic and non-metallic products from .010" to 1.000" diameters on production screw machine equipment; from 1" to 14" diameters on production CNC lathe equipment; and up to 20" x 40" production 4-axis vertical millwork. Seastrom Mfg. Co., Inc.; Tel: 800-634-2356; Fax: 208-734-7222; e-mail: seaeng@micron.net

**Seastrom Mfg. Co. Inc.**

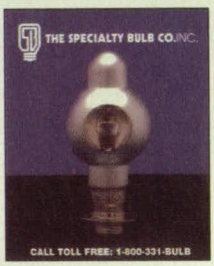
**For More Information Circle No. 613**


## FREE 1999 PC & PCMCIA SOLUTIONS HANDBOOK

Quatech's new 1999 product handbook details our extensive line of quality communication, data acquisition, and signal conditioning products for PCMCIA, ISA, PCI, and USB. New for 1999 are 2-8 port RS-232 and RS-422/485 PCI serial adapters and 2 & 4 port RS-232 USB serial adapters. Product overviews, photos, and complete technical specifications are provided. For your free copy call 1-800-553-1170, e-mail sales@quatech.com, or visit our Web site at www.quatech.com.

**Quatech, Inc.**

**For More Information Circle No. 614**

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**The Specialty Bulb Co. Inc.**

**For More Information Circle No. 615**


## 1999 PCMCIA PRODUCTS CATALOG

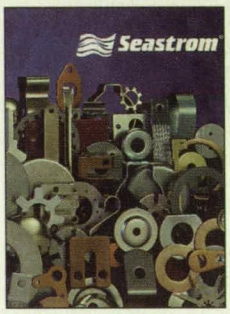
The new 1999 Envoy Data PCMCIA source catalog features the latest PCMCIA drives USB, PCI, and SCSI.

- Rechargeable SRAM Cards, Linear Flash Cards for Routers, Solid State Flash Drives
- PC Card Drives IDE and PC/104 Bus
- I/O Products, Fax/Data, Ethernet Cards
- Digital Photography and PDA Packages
- Technical Application Notes

Envoy Data Corp., 6 East Palo Verde, Ste. 3, Gilbert, AZ 85296; Tel: 800-368-6971; 602-892-0954; Fax: 602-892-0029; e-mail: info@envoydata.com; www.envoydata.com

**Envoy Data Corporation**

**For More Information Circle No. 616**

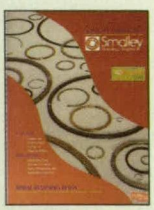



## THE SOURCE FOR ELECTRONIC & MECHANICAL HARDWARE

Seastrom takes pride in offering one of the widest selections of standard electronic and assembly hardware available from stock. Seastrom's 66-A Catalog provides a complete source for over 45,000 products. For a free 550-page catalog, call 800-634-2356.

**Seastrom Manufacturing Co. Inc.**

**For More Information Circle No. 617**




## SPIRAL RETAINING RING CATALOG NO. RR-98

Our newly released 56-page Catalog No. RR-98 offers more than 2000 standard retaining rings, stocked in diameters from 1/2" to 16" (12mm to 280mm), in both English and metric sizes and in carbon and stainless steel. Also included are a Ring Selection Guide; comprehensive Engineering Design Formulas; and data for materials, shear, bending, RPM, installation stress and groove design. Special rings are easy, too! Our no-tooling-cost Edgewinding process enables two-week deliveries for most sizes. Smalley Steel Ring Co., 385 Gilman Ave., Wheeling, IL 60090; Tel: 847-537-7600; Fax: 847-537-7698; www.smalley.com

**Smalley Steel Ring Co.**

**For More Information Circle No. 618**


## INTERNALLY GAGED FORCE TRANSDUCERS

Catalogs describe a complete line of force transducers manufactured by Strainsert. Transducers include: flat load cells, tension and compression from 250 to 2 million pounds; clevis pins with 0-10 vdc and 4-20 ma outputs; tension links up to 400,000 pounds; load-sensing bolts and studs; and load indicators. "Special" designs are invited. Strainsert, Union Hill Industrial Park, West Conshohocken, PA 19428; Tel: 610-825-3310; Fax: 610-825-1734.

**Strainsert**

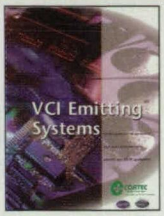
**For More Information Circle No. 619**

## VACUUM PUMP VIBRATION ISOLATORS

The NEC vibration isolators effectively remove turbo-molecular and cryo-pump vibrations. Two models are available in elastomer and air-isolated versions. They are UHV compatible, have short insertion lengths, and high conductance. A wide variety of flanges are available. National Electrostatics Corp., 7540 Graber Rd., Box 620310, Middleton, WI 53562-0310; Tel: 608-831-7600; Fax: 608-256-4103; http://www.pelletron.com; e-mail: nec@pelletron.com

**National Electrostatics Corp.**

**For More Information Circle No. 620**

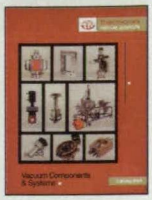



## SAFEGUARD ELECTRONICS WITH PROTECTIVE STICK-UPS

Protect your vital electronic and electrical circuitry against corrosion for up to two years. You can now easily beat the corrosive attack from industrial, marine, and tropical climates. Cortec stick-up emitters install in seconds and require no monitoring or maintenance. These patented emitters conform to many manufacturing and military specifications. Cortec Corporation, 4119 White Bear Parkway, St. Paul, MN 55110; Tel: 651-429-1100; 1-800-4-CORTEC; Fax: 651-429-1122; www.cortecvci.com

**Cortec Corporation**

**For More Information Circle No. 621**



## VACUUM SYSTEMS & COMPONENTS

Thermionics Vacuum Products vacuum systems and components include: Hanks HM2 e-Gun™ evaporation sources; PyraFlat™ rectangular and other flanges, fittings; M.E.S.C./M.E.S.A.-compatible rectangular gate valves, poppet valves; DRS-1000™ in-situ, non-contact substrate temperature control system; sample handling and transfer systems; ion pumps; mat*TC*hed™ thermocouple gauges; mechanical, electrical, and fluid feedthroughs; and materials and surface science. Thermionics Vacuum Products, 231-B Otto St., Port Townsend, WA 98368; Tel: 800-962-2310; Fax: 360-385-6617; e-mail: sales@thermionics.com; www.thermionics.com

**Thermionics Vacuum Products**

**For More Information Circle No. 622**


## OMEGA ENGINEERING, INC. SOFTWARE ON CD

OMEGA has just released its latest Data Acquisition CD. The CD contains the complete 600-page handbook in electronic format. It also includes product and demonstration software, a corporate video, and an electronic copy of OMEGA's latest technical publication: Transactions in Measurement and Control: Volume 2 - Data Acquisition. To request a free CD, contact OMEGA Engineering, Inc. at www.daiseee.com or call 1-800-327-4333. To obtain a CD request form by fax, call 1-800-848-4271 from any Touch Tone phone and request Document #9990.

**OMEGA Engineering, Inc.**

**For More Information Circle No. 623**


## LAYUP MOLDS FOR COMPOSITES DRASTICALLY CUT TIME & COST

The patented Magnaplate CMPT® process is a "breakthrough" in layup-mold technology that saves time and costs for fabricators of large, contoured, reinforced composite parts. This dense, multi-directional metal-weaving process eliminates machining toolfaces from large, expensive metal ingots or castings. Magnaplate CMPT reduces production time for large toolfaces to as little six weeks while slashing costs by one third. General Magnaplate Corp., 1331 Route 1, Linden, NJ 07036; Tel: 800-852-3301; Fax: 908-862-6110; e-mail: info@magnaplate.com; www.magnaplate.com

**General Magnaplate Corp.**

**For More Information Circle No. 624**


## NEW BEARINGS CATALOG B605

Rod Ends and Spherical Bearings have been added to this new 200-page catalog describing a full line of more than 19,000 ball bearings, thrust bearings, sleeve bearings, needle bearings, roller clutches, guide wheels & rail systems, linear ball bearings, aluminum lined linear bearings, and inner and outer ring spacers. A technical section is included to help designers/engineers plan, design, and specify bearings. Quality Bearings & Components; Tel: 516-616-0436; Fax: 516-616-0443; www.qbcbearings.com

**Quality Bearings & Components**

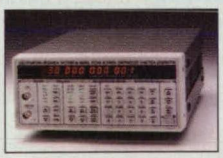
**For More Information Circle No. 625**


## ELECTRONICS TOOLS, KITS, CASES, AND TEST EQUIPMENT

SPC's free 1999 catalog features 384 pages of installation, field-service, and repair tools, tool kits, cases, and test equipment. More than 100 standard tool kits are available, along with modified and custom kits. Electronic test equipment includes DMMs, datacom testers, oscilloscopes, power-analysis equipment, and more. The catalog offers product photos, descriptions, specifications, price breaks, and immediate delivery. Specialized Products Co., 1100 S. Kimball Ave., Southlake, TX 76092; Tel: 800-866-5353; Fax: 800-234-8286; e-mail: SPC@specialized.net; www.specialized.net

**Specialized Products Co.**

**For More Information Circle No. 626**



## 30 MHZ FUNCTION AND ARBITRARY WAVEFORM GENERATOR

The DS345 Function Generator creates synthesized (DDS) sine, square, triangle, and ramp waveforms with 1 microHz frequency resolution. Arbitrary waveforms of up to 16k points with 12-bit resolution can also be generated. Capabilities include AM, FM, PM, and burst mode as well as linear and logarithmic frequency sweeps. The GPIB and RS-232 interface option provides easy communication with computers and includes software for creating arbitrary waveforms. U.S. list price: $1,595. Stanford Research Systems; Tel: 408-744-9040; e-mail: info@srsys.com; www.srsys.com

**Stanford Research Systems**

**For More Information Circle No. 627**


## DATA LOGGER, LOW-COST PC COMPATIBLE

DCC's data logger displays eight thermocouple channels on monitor, printer, and disk for $349 complete. Designed specifically for laboratory and industrial temperature monitoring, it is easy to set up. An RS-232 interface powers the converter, eliminating sensor wires at the computer. QuickBasic® MS source code and compiled program are provided. Other features include 16-channel and linear options. DCC Corporation, 7300 N. Crescent Blvd., Pennsauken, NJ 08110; Tel: 609-662-7272; Fax: 609-662-7862; www.thomasregister.com/dcc

**DCC Corporation**

**For More Information Circle No. 628**

## *New!* Solar System T-Shirt

**Dramatic full-color illustration on high-quality black cotton shirt. Available while supplies last in children's sizes 2-4, 6-8, 10-12, or 14-16; adult sizes M, L, XL, or XXL. $15.95 each.**

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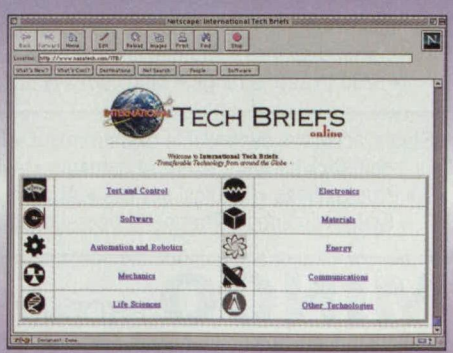


# New on the MARKET

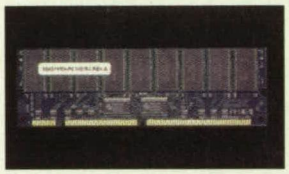
## Programmable Oscillator

Ecliptek Corp., Costa Mesa, CA, has introduced the EPO™ series of programmable clock oscillators. Features include custom or standard frequencies ranging from 1 MHz to 125 MHz. Performance options include tri-state or power-down function, ±50 ppm or ±100 ppm frequency stability, and CMOS or TTL output duty cycle. The EP1100 and EP2500 are 5V versions; the EP1300 and EP2600 offer 3.3V for lower-voltage applications. The series is offered in a 14-pin dip or 8-pin dip hermetically sealed pacakage and a ceramic SMD package. **Circle No. 720**

## Flexible Epoxy

Cotronics Corp., Brooklyn, NY, offers Duralco™ 125 "Stress Free" epoxy, which combines resins and hardeners with specialty conductive fillers to provide continuous service to 450°F. The epoxy is formulated to cure at room temperature, forming flexible, electrically conductive bonds resistant to moisture, chemicals, and solvents. Applications include flexible circuits, solder replacement, bonding semiconductors, EMI shielding, wire tacking, and heat-element assembly. **Circle No. 725**

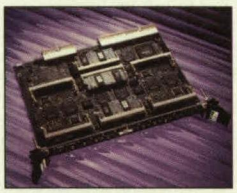




## Memory Modules

Camintonn Corp., Irvine, CA, has introduced a line of PC100-compatible memory modules for Compaq's new family of AP Professional and SP700 workstations. The 100% compatible memory is available in 32-, 64-, 128-, and 256-MB modules for the AP series; and 128-, 256-, and 512-MB modules for the SP700. The modules incorporate a patented chip-stacking technology designed to allow maximum system-memory capacity. The 128-Mbit SDRAM stacks, used on the 256-MB module, are built with 64-Mbit SDRAM; the 256-Mbit SDRAM stacks, used on the 512-MB module, are built with new 128-Mbit SDRAM chips. **Circle No. 723**

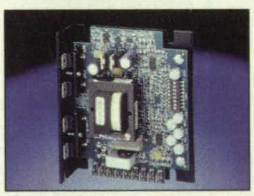
## CompactPCI® Board



The Goblin™ from BittWare Research Systems, Concord, NH, is a seven-SHARC® CompactPCI® board with 840 MFLOPS of processing power. Of the seven SHARCs, one functions as the CompactPCI interface, leaving the remaining six for high-speed processing. The Goblin offers up to 448 MB DRAM with 560 MB/second overall memory bandwidth. Features include 14 external link ports, allowing several boards to be linked together for greater processing power. The network of link ports allows multiple boards to communicate within a system. Uses include I/O-intensive applications in the military, medical, and telecommunications industries. **Circle No. 724**

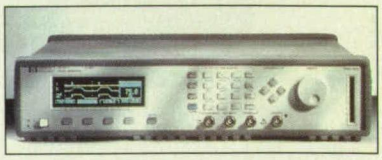
## Speed Control

The UPM unfiltered SCR speed control from Bodine Electric, Chicago, IL, features adjustable control parameters for applications such as speed control for brush-type DC fractional horsepower gearmotors and motors. Two models are available, with either a plug-in terminal or 1/4-inch quick connect tab features. The seven dip switches allow system configuration of speed regulation and current limit. Five adjustable control parameters are available to modify minimum/maximum speed limit, torque limit, and acceleration/deceleration times. It operates from either 115 or 230 VAC with an output of either 0-90 or 0-180 VDC. **Circle No. 721**



## Pulse Generator

Hewlett-Packard, Palo Alto, CA, has introduced the HP 81101A 50-MHz programmable pulse generator designed to help engineers in manufacturing and service provisioning perform parametric verification tests on digital devices and systems. Features include fast, variable transition time, and flexible amplitude and duty cycles. Engineers can save test settings and program the HP 81101A for automated test routines. The settings can be used on other pulse/pattern generators in the HP 81100 family, which includes four models with frequencies from 50 to 660 MHz. **Circle No. 726**



## Pentium II CPU Board

The MantaRay™ integrated Pentium II passive backplane CPU board from I-Bus, San Diego, CA, uses Intel's 440BX chipset. MantaRay is designed to support processor speeds up to 450 MHz with a 100-MHz external clock, and up to 333 MHz with a 66-MHz external clock. Options include on-board Ethernet, SCSI, and video. The board features two RS-232-compatible serial ports with transfer rates programmable to 50K baud independently; a USB; a floppy-drive controller; and a real-time clock backed by an on-board field-replaceable battery. The PCI IDE interface supports four enhanced IDE devices with up to mode 4 PIO. **Circle No. 727**

## Four-Channel Recorder

The 8835 Memory HiCorder from Hioki, Cranbury, NJ, is a lightweight, compact unit that includes a color-LCD measurement display screen. It is designed to provide simultaneous sampling rates on all channels of one million samples per second, allowing high-speed waveforms to be performed. Other features include support for data transfer to computer via PC card or floppy disk, large-capacity memory, built-in help function, and a voltage-drop detector. Applications include telecommunications, mechanical engineering, and automotive diagnostics and repairs. **Circle No. 728**

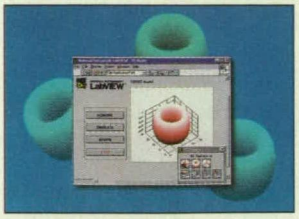
## Rotary Sensors

The Series 9800 rotary sensors from Duncan Electronics Division of BEI Sensors & Systems, Tustin, CA, are designed for a range of industrial control applications. The body design minimizes stress points and is resistant to leakage or damage from contaminants and moisture. Standard features include conductive plastic resistive technology, up to 180-degree mechanical rotation, resistance of 5,000 ohms ±20%, and ±2% standard linearity. The sensors provide readings over a temperature range of -40°C to +135°C, vibration of 15 Gs, and humidity levels to 95% at 38°C. **Circle No. 739**

## Ball and Roller Slides

Del-Tron Precision, Bethel, CT, has introduced a line of ball and cross roller slides with straight-line accuracy of 0.000040" per inch of travel. They offer repeatability of 0.000020" and carriage surface flatness of 0.0001" per inch while bearing way surfaces are held to submicron tolerances. The slides have stainless steel balls, rollers, ways, pre-loaded gibs, and fasteners. Ball slides are offered in low-profile and flange base styles from 0.5" to 10" travel; crossed roller slides are offered in low-profile and flange base styles from 1" to 10" travel. **Circle No. 751**

# New on DISK



## Application Development

National Instruments, Austin, TX, has announced version 5.1 of the LabVIEW application development environment for measurement and automation. The new modular application architecture allows users to create smaller executables to gain performance and decrease memory usage. The new version also extends its use of ActiveX technology to integrate the math and interactive analysis capabilities of The MathWorks MATLAB and National Instruments HiQ™. Built-in Web tools enable publishing of VI front panels. DataSocket™ technology enables users to share data with other Internet-enabled applications. Other enhancements include more than 100 advanced mathematics routines, a new 3D graph control for modeling and visualization, scalable front panels, improved report generation, and enhanced graphics for custom drawing and animation. **Circle No. 718**

## Computer-Aided Testing

Computer Aided Test Suite™ (CATS) from Spectral Dynamics, San Jose, CA, is designed to make all test data accessible to anyone who needs it, using OLE technology to distribute live, dynamic reports that contain an interactive display of relevant data. Data, both real-time and stored, can be made available for any type of viewing or analysis, instantly, via a local network or across the Internet. CATS includes LabLink™, which incorporates existing test equipment into an integrated test environment. Users choose an instrument interface; all data from that system then becomes virtual channel data in CATS. VirtualCalculator™ enables users to perform array math, constants, and arithmetic and trigonometric operations. QuickAccess™ allows users to search databases and build data-storage templates. **Circle No. 716**

## CFD Analysis Software

Amtec Engineering, Bellevue, WA, offers CFD Analyzer, which provides users of Tecplot engineering and visualization software with the capabilities to select predefined functions to calculate additional computational fluid dynamics (CFD) variables for performing numerical integrations. It loads automatically at run time and becomes part of the Tools menu, with dialog boxes to facilitate variable calculation and integration. The CFD Analyzer enables users to enhance data by creating new variables from a list of functions defining grid properties and flow-field variables. The new variables are available immediately for viewing in Tecplot. **Circle No. 717**

## 2D/3D CAE Tools

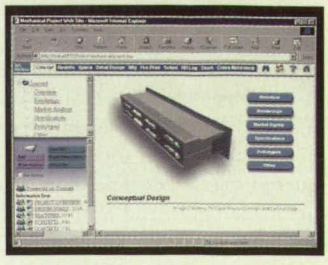
Integrated Engineering Software, Winnipeg, Manitoba, Canada, has released the latest version of its 2D/3D CAE software tools based on Boundary Element Method (BEM) technology. Features include a customizable GUI utilizing Windows-style toolbars. Users can choose point-and-click operation of toolbars and icons, or a drop-down command structure. Toolbars can be resized and placed according to user preference. A set of updated shortcut keys for the View commands leaves the keys "hot" and ready to use. **Circle No. 714**


## Thermal Analysis

Harvard Thermal, Harvard, MA, has released Version 3 of Thermal Analysis System (TAS), a Windows 95/98/NT application offering a graphical preprocessor designed for fast generation of complex geometry. TAS also interfaces with other thermal tools including SINDA/G, SINDA/FLUINT, and TRASYS, in addition to FEA tools such as MSC/NASTRAN, ANSYS, and FEMAP. **Circle No. 713**

## SolidWorks Add-In Module

ActiveProject™ Assembly Publisher for SolidWorks® 98Plus from Framework Technologies Corp., Burlington, MA, enables mechanical designers to instantly publish a complete SolidWorks assembly model as a fully developed Project Web Site. The software builds a collaborative, Web-based project communication system around a SolidWorks model. Authorized participants can contribute to the site, comment, and perform on-line reviews with revision history of SolidWorks models and other documents. Notifications of changes are automatically sent via e-mail to team members. **Circle No. 773**

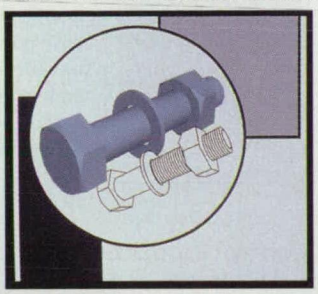


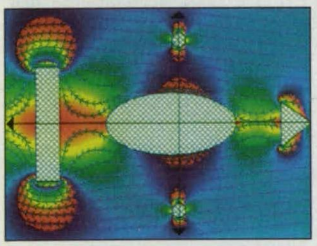
## Machine Vision Software

Imagraph, Chelmsford, MA, offers HLImage++™ 99 machine vision and image processing software that features a digital I/O tool, serial I/O tool, barcode tool, WAV player tool, and an I-Series picture tool. The software is a GUI-based program that includes more than 20 imaging tools such as Blob Analysis, Filter, Histogram, Measurement, Calibration, as well as file input/output, image display, zooming, and region-of-interest setting. **Circle No. 772**

## AutoCAD Modules

EMT Software, Bellingham, WA, offers a Survival Kit of six enhancement modules for AutoCAD R14 that also includes support for Autodesk's Mechanical Desktop 2.0 and 3.0. The modules feature dockable toolbars and on-line Windows help. Among the modules is MECH 2D/3D for creating fasteners, steel shapes, and holes parametrically. MECH SHAFT creates 2D and 3D bearings, gears, splines, grooves, holes, and keyways. MAKE IT3D converts 2D orthographic views into solid 3D models; MAKE IT2D automatically creates 2D views from 3D solids; and MECH UTILITY provides automatic dimensioning and parts list generation. MLIB is a graphical block manager. **Circle No. 774**



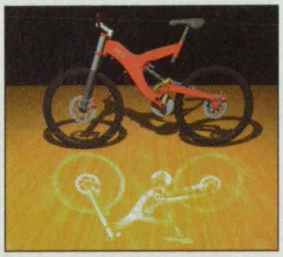


## Flow Visualization

2DFLOW$^{PLUS®}$ V2.5 from Dynaflow, Fulton, MD, visualizes flows induced by the distributions of point and line singularities such as vortices, dipoles, and sources. It graphically illustrates the use of potential flow theory by the combination of a uniform flow with a variety of singularities to simulate a range of fluid mechanics problems. Features include point-and-click singularity insertion and editing, solid boundaries and objects of arbitrary shapes to be inserted in the flow, and the ability to study internal and external flows. Users can compute and view flow trajectories, equipotential lines, stream lines, pressures, and velocity vectors using contours, iso-quantity lines, and trajectories. **Circle No. 775**

## Product Communication

Immersive Design, Acton, MA, has introduced IPA 5.0 Windows-based 3D product communication software for design and manufacturing. IPA (Interactive Product Animator) allows users at any point in the design cycle to communicate product design changes and recommendations back to the design environment. The software also helps manufacturers communicate by the Internet with suppliers. Enhancements include improved text and annotation capabilities for text mark-up, and upgrades to animation attributes, including the ability to translate complex designs into animations, and transform designs into photorealistic 3D mini-movies. **Circle No. 776**



# New LITERATURE

## Single-Plane Balancing


Balmac, Hilliard, OH, offers The Balmac "B" Book for single-plane balancing to maintenance and plant personnel responsible for rotating machinery. This pocket-sized guide provides illustrated, step-by-step instructions for balancing a fan wheel using the Balmac Model 216-D vibration analyzer/balancer with strobe light. **Circle No. 732**


## Self-Locking Fasteners

PEM® self-locking, self-clinching fasteners with the PEMFLEX® self-locking feature are described in a four-page brochure from Penn Engineering & Manufacturing Corp., Danboro, PA. The PEMFLEX design utilizes two rugged, semicircular flexing jaws instead of several less-supported segments. **Circle No. 753**



## Vibration Isolation

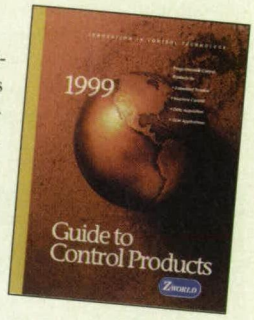
Sorbothane, Kent, OH, offers a brochure describing vibration-isolation and impact-absorption material. It also includes a new line of advanced vibration-isolation/shock-absorption products. The brochure outlines engineering and manufacturing capabilities, along with applications for the materials and products. **Circle No. 730**


## Flexible Fiberscopes

A two-page bulletin from Lenox Instrument, Trevose, PA, describes an expanded line of flexible fiberscopes. The waterproof probes have a woven stainless steel sheathing to protect the fiber optics. Products include 3.5-mm and 6-mm fiberscopes with two-way remote articulation; 7.5-mm and 10-mm models have four-way remote articulation. **Circle No. 733**

## Control Products

Z-World, Davis, CA, has released an 88-page 1999 Guide to Control Products Master Catalog, which features customizable board-level, packaged, low-power, and expansion controllers. It also offers an expanded selection of programmable touchscreen and display products. **Circle No. 734**



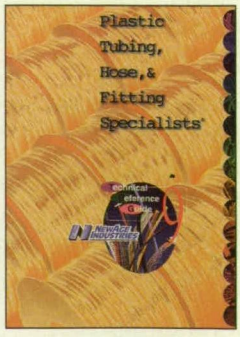


## Workplace Safety

The Protection Zone™ from Cole-Parmer Instrument, Vernon Hills, IL, is a 200-page catalog of worker-protection and workplace safety equipment. Products range from personal protective gear, such as gloves and apparel, to complex monitoring and documentation equipment. **Circle No. 735**

## Tubing and Hose Products

New Age Industries, Willow Grove, PA, has released the Technical Reference Guide 9 (TRG9) full-line tubing and hose product catalog. It features plastic and rubber tubing and hose, plastic and metal fittings, and clamps. Among several new products are PVC air hose; industrial-grade PVC tubing and hose; nylon-12 tubing; and platinum-cured, braid-reinforced silicon hose. **Circle No. 736**

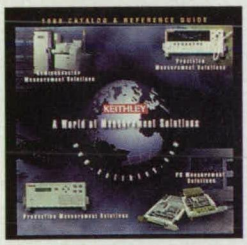



## Test Solutions Catalog

Geotest/Marvin Test Systems, Santa Ana, CA, offers a 120-page PC-based test solutions source book, which includes more than 100 off-the-shelf products, plus 50 new hardware and software products. The catalog features ATE platforms, analog measurement instruments, stimulus instruments, digital instruments, switching cards, and software for use in ATE applications. **Circle No. 752**

## Vibration Isolation


Technical Manufacturing Corp., Peabody, MA, offers a 96-page catalog of vibration isolation systems and equipment, including cleanroom, laboratory, and optical tables; tabletop, floor, and sub-floor platforms and stands; breadboards; isolators; and accessories. Also included is the new STACIS™ 2000 piezoelectric active vibration control system. **Circle No. 754**




## Instrumentation Guide

Keithley Instruments, Cleveland, OH, has introduced a 700-page full-line catalog and reference guide to electronic test and measurement instrumentation, and data acquisition hardware and software. Products include DMMs, electrometers, voltmeters, power supplies, switching systems, and PCI, ISA, PCMCIA, and IEEE data acquisition boards. Also featured is an array of software to complement measurement systems. **Circle No. 698**


## Motor Drives

A brochure describing the SCF Series of sub-micro drives is available from AC Technology Corp., Uxbridge, MA. The drives feature adjustable DC injection braking, slip compensation, current limit to 180% with frequency foldback, and fault history of eight previous faults. Applications include packaging machinery, conveyors, pumps, fans, and centrifuges. **Circle No. 699**

## Glass Products

Literature from Pope Scientific, Saukville, WI, describes custom glass products that can be manufactured, including glass OEM parts, small and large items, and single pieces through large production runs. Other products include apparatus, tubing, rods, connectors, adapters, and coated glass. **Circle No. 731**

# Advertisers Index

| Company | Web Site | Circle Number | Page |
|---|---|---|---|
| Abaris Training Resources, Inc. | www.abaris.com | 423 | 45 |
| Algor, Inc. | www.algor.com | 521, 528, 607, 608 | 7, 35, 55 |
| Amtec Engineering, Inc. | www.amtec.com | 407 | 18 |
| Ansoft Corporation | www.ansoft.com | 481 | 5a |
| APD | | 606 | 55 |
| API Motion Inc. | www.apimotion.com | 641 | 12b |
| Astro-Med, Inc. | www.astro-med.com | 563 | 13 |
| Azonix | www.azonix.com | 603 | 55 |
| Belt Technologies, Inc. | www.BeltTechnologies.com | 409 | 22 |
| Buckeye ShapeForm | www.buckeyeshapeform.com | 456 | 10a |
| C-Flex Bearing Co., Inc. | www.c-flex.com | 647 | 8b |
| Continuum | www.continuumlasers.com | 540 | COV III |
| Cortec Corporation | www.cortecvci.com | 621 | 57 |
| Dataq Instruments | www.dataq.com | 415 | 32 |
| Datum, Bancomm-Timing Division | www.datum.com | 420 | 34 |
| DCC Corp. | www.thomasregister.com/dcc | 628 | 57 |
| Del-Tron Precision, Inc. | www.deltron.com | 644 | 4b |
| Digi-Key Corporation | www.digikey.com | 550 | 3 |
| Dimco-Gray | www.dimco-gray.com | 430 | 61 |
| Dolch Computer Systems, Inc. | www.dolchdpg.com | 414 | 30 |
| DTM Corporation | www.dtm-corp.com | 411 | 26 |
| DuPont Vespel | www.dupont.com/enggpolymers | 470 | 14a-15a |
| Edmund Scientific | www.edsci.com | 605 | 55 |
| EGC enterprises incorp. | www.egc-ent.com | 421 | 43 |
| electrocube | | 458 | 12a |
| Envoy Data Corporation | www.envoydata.com | 616 | 56 |
| Ergotron | www.ergotron.com | 579 | 5 |
| Federal Laboratory Consortium | www.federalabs.org | | 49A-D |
| Firestone Industrial Products Co. | | 611 | 56 |
| Fluoramics, Inc., TuFoil | www.tufoil.com | 417 | 38 |
| Gage Applied Sciences Inc | www.gage-applied.com/ad/nasa499.htm | 408 | 11 |
| Galil Motion Control. Inc. | www.galimc.com | 640 | 12b |
| General Magnaplate Corp. | www.magnaplate.com | 624 | 57 |
| Geotest/Marvin Test Systems, Inc. | www.geotestinc.com | 462, 463, 604 | 11a, 13a, 55 |
| Gordon Products, Inc. | www.gordonproducts.com | 460, 461 | 6a |
| HELICAL Products Company, Inc. | www.Heli-Cal.com | 652 | 13b |
| Hewlett-Packard Co., Benchtop DMM | www.hp.com/info/HP34401A | 526 | 27 |
| Hewlett-Packard Co., Design Jet | www.hp.com/go/Large-format/info/4914 | 531 | 16-17 |
| Hiram Jones Electronics, Inc. | | 612 | 56 |
| Interfaces By Cramer | www.keyboardchair.com | 427 | 59 |
| Intusoft | www.intusoft.com | 453 | 4a |
| Invention Machine Corporation | www.invention.machine.com | 577 | 4 |
| IOtech, Inc. | www.iotech.com | 401,402 | 25A-B |
| ITTools | www.ittools.com | 433 | 63 |
| Jonathan | www.jonathanmfg.com | 649 | 11b |
| Joyce/Dayton Corp. | www.joycejacks.com | 651 | 13b |
| Kaman Instrumentation | www.kamaninstrumentation.com | 650 | 12b |
| Keithley Instruments, Inc. | www.keithley.com | 534, 609 | 31, 56 |
| Kingston Technology Company | www.kingston.com/storage | 507 | 2 |
| LPTek Corp. | www.lptek.com | 419 | 40 |
| Master Bond Inc. | | 434, 457 | 63, 12a |
| The MathWorks, Inc. | www.mathworks.com/ntbv | 542 | 8A-B, 9 |
| Metrum-Datatape | www.metrum-datatape.com | 435 | 42 |
| Microcal Software, Inc. | www.microcal.com | 416 | 33 |
| Minalex | | 600 | 55 |
| Minco Products, Inc. | | 426 | 58 |
| National Electrostatics Corp. | www.pelletron.com | 620 | 56 |
| National Instruments | www.natinst.com/labview | 601 | 55 |
| National Instruments Corporation | www.natinst.com/labview, www.natinst.com/info/pcidaq, www.natinst.com/cvi | 565, 413, 418 | COV II, 29, 39 |
| Newport | www.newport.com, www.ramoptical.com | 646 | 7b |
| NOOK Industries, Inc. | www.nookind.com | 648 | 9b |
| Olympus America Inc. | www.olympusipg.com | 404 | 48 |
| Omega Engineering, Inc. | www.omega.com | 551-554, 623 | 1, 57 |
| Omega Shielding Products Inc. | www.omegashielding.com | 425 | 50 |
| Omnetics Connector Corp. | | 490 | 14a |
| OrCAD, Inc. | www.orcad.com/pspice | 482 | 7a |
| Oriel Instruments | www.oriel.com | | 21 |
| Penn Engineering & Mfg. Corp. | www.pemnet.com | 602 | 55 |
| Presray Corporation | www.presray.com | 412 | 28 |
| Quality Bearing & Components | www.qbcbearings.com | 625 | 57 |
| Quatech, Inc. | www.quatech.com | 614 | 56 |
| Research Systems, Inc. | www.rsinc.com | 575 | COV IV |
| RGB Spectrum | www.rgb.com | 406 | 10 |
| Rifocs Corporation | www.rifocs.com | 455 | 10a |
| RMB Miniature Bearings, Inc. | www.smoovy.com | 642 | 1b |
| Rockwell Automation/ Allen-Bradley | www.ab.com | 645 | 5b |
| Sanyo | www.thomasregister.com/sanyoenergy | 454 | 8a-9a |
| Seal Master Corporation | www.sealmaster.com | 431 | 61 |
| Seastrom Mfg. Co. Inc. | | 613, 617 | 56 |
| Sifco Selective Plating | www.brushplating.com | 429 | 60 |
| Smalley Steel Ring Co. | www.smalley.com | 618 | 56 |
| Sony Precision Technology of America, Inc. | www.sonyprecision.com | 513 | 1a |
| Sorbothane, Inc. | www.sorbothane.com | 432 | 62 |
| Specialized Products Co. | www.specialized.net | 626 | 57 |
| The Specialty Bulb Co. Inc. | www.bulbspecialists.com | 615 | 56 |
| SPIE | www.spie.org/info/annualmeeting/ | | 54 |
| Stanford Research Systems | www.srsys.com | 538, 627 | 37, 57 |
| Strainsert | | 619 | 56 |
| Synrad, Inc. | www.synrad.com/fenix | 405 | 8 |
| TAL Technologies, Inc. | www.taltech.com | 610 | 56 |
| Tamura Corporation of America | | 480 | 3a |
| Thermionics Vacuum Products | www.thermionics.com | 622 | 57 |
| THK America, Inc. | www.thk.com | 643 | 3b |
| Vaisala | www.vaisala.com/inc/ssdcat | 424 | 50 |
| Velmex, Inc. | www.velmex.com | 422 | 45 |
| Visionary Design Systems, Inc. | www.ironcad.com | 558 | 15 |
| Wolfram Research, Inc. | www.wolfram.com/eng/ntb | 546 | 19 |
| The Zippertubing Co. | www.zippertubing.com | 428 | 59 |

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